



EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATION SUITABILITY IN THIMMAJIPET MANDAL, MAHABUBNAGAR DISTRICT

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ABSTRACT

Georeferenced groundwater samples collected from Thimmajipet mandal, Mahabubnagar district were analyzed and evaluated for their suitability for irrigation. Out of 49 samples, 12 per cent samples recorded pH > 8.5 and electrical conductivity varied from 500 to 5130 $\mu\text{S cm}^{-1}$. All the samples have high Mg^{2+} content and 92 and 94 per cent samples have high Ca^{2+} and Na^+ , respectively. Among the total groundwater samples 59 per cent have high sodium hazard, 80 per cent with high magnesium hazard, 7 per cent with high Mg/Ca ratio and 100 per cent with very high permeability index. Water samples were classified as C3S1 (29%), C3S2 (39%), C2S2 (2%) and C2S1 (4%). In general, the groundwater in Thimmajipet mandal is unsafe for long-term irrigation use.

KEYWORDS: Groundwater quality, Irrigation suitability, Permeability index, Sodium hazard.

INTRODUCTION

Groundwater is one of the prime sources for irrigation especially in arid and semi-arid regions of India. Tube wells are major source of irrigation and their share has increased from 1 per cent in 1960–61 to 37 per cent in 1999–2000 (MoRD, 2006). Telangana, located in the southern Deccan plateau region receives very less mean annual rainfall (MAR) with uneven distribution and the agriculture sector registered a mixed growth rate varying from 25.2 to -10.0 per cent during the period 2005-06 to 2013-14 due to frequent droughts. The cropping intensity has increased from 109 per cent in 1993-94 to 127 per cent in 2013-14 with a major shift in irrigation pattern making it more costly for the farmers, highly uncertain and unsustainable (Rao, 2014). The vagaries of climate change have put the seasonal agricultural system and agriculture dependent economy of Telangana in jeopardy.

The occurrence and behavior of groundwater is an outcome of combined interplay of hydrological, geological, structural and climatological factors. The composition of groundwater is determined by their source and the type of strata over which they flow (Rengaraj, 1996) and the kinds of salts found in them depends on the laws of dissolution. The suitability of water for irrigation is influenced by many factors such as quality of water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil

(Michael, 1990). The potential evapo-transpiration largely exceeds precipitation in the semi-arid regions, thereby increasing the probability of soil salinity or sodicity development if the groundwater used for irrigation is poor in quality. Telangana is now facing both depleting groundwater table and deficit rains and allocation of natural resources like groundwater to different sectors *viz.*, agriculture, industry and drinking water use has become a challenging task for policy makers. The steady decline in groundwater level warrants immediate attention on both quantity and quality of groundwater. The groundwater quality is deteriorating particularly with high salt content and limits its use for agriculture in Mahabubnagar district (CWGB, 2013). In the context of above scenario, several studies need to be conducted to assess the potential threat of poor quality groundwater. The present study is one such type, which attempts to evaluate the groundwater for its quality and suitability for irrigation in Thimmajipet mandal, Mahabubnagar district.

MATERIALS AND METHODS

Description of the Study Area

Thimmajipet mandal is part of Mahabubnagar district, located between 16°55' N latitude and 78°20' E longitude with an elevation of 481 m above mean sea level in southern Telangana plateau, (Agro Ecological Sub Region 7.2). The total geographical area is 200.90 km²

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and covered by granite, peninsular gneiss, basalt, and mixed granite and basaltic rocks. The MAR varies from 450-550 mm. Gross cropped and irrigated areas are 14,020 and 1,960 ha respectively. Major crops grown during *kharif* are cotton (*Gossypium hirsutum*), maize (*Zea mays*) followed by paddy (*Oryza sativa*), red gram (*Cajanus cajan*) and castor (*Ricinus communis*). In *Rabi* groundnut (*Arachis hypogaea*) is the major crop followed by paddy and maize. The length of growing period (LGP) is 90-120 days. Tube wells are the major sources of water irrigating more than 90 per cent of the irrigated area.

Sampling and Analysis

Forty nine geo-referenced groundwater samples were collected from 19 villages of the Thimmajipet mandal (Fig.I) during February 2015 from tube wells in stopper fitted plastic bottles and stored at a temperature below 4°C prior to analysis in the laboratory. The samples were analyzed for pH, electrical conductivity, cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) and anions (Cl^- , CO_3^{2-} , HCO_3^- , SO_4^{2-} and BO_3^{3-}) using standard procedures (APHA, 2005). Important indicators of water quality for irrigation were derived using the guidelines given by Ayers and Westcot (1985). Parameters such as pH, electrical conductivity (EC), soluble sodium percentage (SSP), residual sodium carbonate (RSC), potential salinity (PS), magnesium hazard (MH) and permeability index (PI) were used to assess the suitability of water for irrigation purposes.

SSP was calculated by the following equation (Todd, 1995).

$$SSP = \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$$

RSC was calculated according to Gupta and Gupta (1987):

$$RSC = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

PI was calculated according to Doneen (1964) employing the following equation:

$$PI = \frac{Na^+ + HCO_3^-}{Na^+ + Ca^{2+} + Mg^{2+}} \times 100$$

MH was calculated using the following equation (Raghunath, 1987):

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100$$

PS was calculated based on the formula (Hammet, 1992) as:

$$PS = \frac{1}{2} \text{SO}_4^{2-} + \text{Cl}^-$$

RESULTS AND DISCUSSION

Hydrochemistry

pH ranged between 6.91 and 8.91. Among the 49 samples studied, 12% showed pH > 8.5 and may be harmful for plant growth by (Table 1) inducing alkalinity in soils. Electrical conductivity (EC) varied from 500 to 5130 $\mu\text{S cm}^{-1}$ with a mean value 1897 $\mu\text{S cm}^{-1}$ (Table 1) and 20 per cent of water samples have EC more than 2500 $\mu\text{S cm}^{-1}$ which is unsafe for irrigation and may induce strong salinity in irrigated soils (Ayers and Westcot, 1985). Total dissolved solids (TDS) varied from 320 to 3283 mg L^{-1} with a mean value of 1214 mg L^{-1} . According to FAO standards (Table 2), irrigation water with more than TDS > 1500 mg L^{-1} are classified with severe limitation for its use and 20 per cent of the water samples are unsafe for irrigation.

Ionic concentration

The concentration of cations and anions in groundwater depends on the geology, weathering of rocks and soil and water management practices. Calcium (Ca^{2+}) contributes to the hardness of the water and the sources of Ca^{2+} in ground water especially in sedimentary rocks such as calcite, aragonite, gypsum and anhydrite. In the present study, Ca^{2+} varied from 11 to 114 me L^{-1} and Mg^{2+} from 14 to 129 me L^{-1} . The usual range of Ca^{2+} and Mg^{2+} in irrigation water is 0-20 and 0-5 me L^{-1} , respectively and 92 per cent of water samples have Ca^{2+} more than 20 me L^{-1} and all the samples have high Mg^{2+} . The high concentration of Ca^{2+} and Mg^{2+} results in alkalinity of water and induces osmotic stress to the plants. K^+ ranged between 0.13 and 1.97 me L^{-1} while Na^+ varied between 35.65 and 117 me L^{-1} (Table 1). The safe range of Na^+ is 0-40 me L^{-1} and 94 per cent of water samples have high sodium content. Cl^- varied from 5 to 18 me L^{-1} and 39 per cent samples are with moderate Cl^- toxicity, 53 per cent with high toxicity and 8 per cent with very high toxicity according to FAO standards (Ayers and Westcot, 1985). CO_3^{2-} varied from 0 to 10 me L^{-1} , HCO_3^- from 0.3 to 17.5 me L^{-1} , SO_4^{2-} from 0 to 63 me L^{-1} and BO_3^{3-} from 0.2 to 1.25 me L^{-1} .

Evaluation of groundwater quality for irrigation use

Table 1. Summary statistics of groundwater properties in study area

Characteristics	Minimum	Maximum	Mean	Standard Deviation
pH	6.91	8.91	7.82	0.46
EC ($\mu\text{s cm}^{-1}$)	500	5130	1897	1194
TDS (mg L^{-1})	320	3283	1214	764
K^+ (me L^{-1})	0.13	1.97	0.41	0.28
Na^+ (me L^{-1})	35.65	117	69	21.70
Ca^{2+} (me L^{-1})	11	114	32.47	15.57
Mg^{2+} (me L^{-1})	14	129	41.67	22.56
Cl^- (me L^{-1})	5	18	8.65	2.59
CO_3^{2-} (me L^{-1})	0	10	0.73	2.18
HCO_3^- (me L^{-1})	0.3	17.5	10.96	4.09
Boron (mg L^{-1})	0.2	1.25	0.52	0.25
SO_4^{2-} (me L^{-1})	0	63	11.96	11
RSC (me L^{-1})	-89.00	-5.00	-25.38	17.62
SSP (%)	19.74	71.54	48.96	11.38
PS (me L^{-1})	7	40	14	6.93
Magnesium Hazard	26.42	76.09	55.40	9.84

Table 2. Evaluation Criteria of water samples (USSL, 1954 and Ayers and Westcot, 1985)

Water Quality Classes for irrigation				
Salinity Hazard				
Parameters	Classification			
	Excellent	Good	Permissible	Unsuitable
EC (dSm^{-1})	<0.25	0.25-0.75	0.75-2.25	>2.25
TDS (mg L^{-1})	<200	200-500	500-1500	>1500
Soil Water infiltration (Evaluation using EC and SAR together)				
EC (uS cm^{-1})	Class		SAR	Class
<250	C1		>10	S1
250-750	C2		10-18	S2
750-2250	C3		18-26	S3
2250	C4		>26	S4
Specific Ion Toxicity				
Boron (me L^{-1})	Class		Chloride (me L^{-1})	Class
<0.5	Low		<4	Good
0.5-10	Medium		4-7	Medium
1.0-2.0	High		7-12	Unsafe
>2.0	Very high		>12	Very Unsafe

Table 3. Water quality indices of groundwater in the study area

Sample ID	^a SAR	^b RSC	^c SSP	^d PS	^e MH	^f PI
W1	17.90	-35.5	58.29	26	70.37	59
W2	15.77	-12.0	59.72	8	73.21	71
W3	9.97	-12.0	50.79	13	76.09	63
W4	13.10	-15.5	55.43	10	60.00	60
W5	4.73	-64.0	21.97	20	62.77	25
W6	4.86	-89.0	19.74	20	64.95	23
W7	6.57	-41.0	31.41	40	52.94	38
W8	8.06	-22.0	41.60	17	52.38	51
W9	8.56	-17.5	44.16	16	48.28	55
W10	7.08	-84.5	26.20	16	42.42	32
W11	18.43	-19.4	62.21	21	74.19	63
W12	13.26	-13.0	55.75	33	30.91	67
W13	11.30	-13.5	53.66	10	46.81	64
W14	12.44	-17.0	52.87	11	52.46	63
W15	7.53	-22.0	39.78	11	65.63	49
W16	19.54	-13.0	64.37	14	56.90	74
W17	13.47	-13.5	56.83	21	50.00	67
W18	10.08	-25.0	45.02	10	53.33	54
W19	11.37	-11.5	56.45	12	44.74	65
W20	9.94	-27.0	44.70	13	46.67	53
W21	20.10	-12.0	65.99	8	26.42	75
W22	14.82	-22.5	54.90	9	43.84	64
W23	8.30	-31.0	38.09	9	52.22	48
W24	6.74	-36.5	33.31	8	51.11	40
W25	13.92	-24.0	52.61	23	55.13	62
W26	6.48	-26.5	34.84	8	57.53	44
W27	14.80	-16.0	57.10	17	59.02	67
W28	11.99	-23.5	49.18	15	48.68	59
W29	12.73	-71.0	40.69	32	75.88	46
W30	9.69	-29.7	45.51	9	50.00	46
W31	13.24	-20.0	54.97	12	62.07	62
W32	23.15	-5.0	71.54	11	57.14	77
W33	8.68	-24.5	43.47	11	58.73	50
W34	6.30	-25.0	35.70	11	62.50	43
W35	11.81	-28.0	47.90	14	58.54	56
W36	12.87	-23.5	50.45	9	60.76	61
W37	10.55	-22.0	48.64	14	55.74	53
W38	10.43	-28.0	46.03	18	60.81	53
W39	15.56	-9.0	62.60	12	52.38	74
W40	11.01	-21.0	47.65	7	56.94	59
W41	18.89	-12.5	63.21	9	51.67	74
W42	8.62	-15.5	44.97	8	52.73	57
W43	12.18	-20.5	52.14	9	58.06	60
W44	19.31	-8.5	67.44	10	44.19	77
W45	16.40	-27.0	56.79	12	59.74	63
W46	10.64	-18.5	49.12	12	53.33	59
W47	8.93	-35.5	39.41	13	58.06	47
W48	11.55	-19.5	49.47	12	50.72	61
W49	14.11	-19.5	54.34	9	55.71	64

^a: Sodium Adsorption Ratio; ^b: Residual Sodium carbonate;

^c: Soluble Sodium Percentage; ^d: Potential Salinity;

^e: Magnesium Hazard; ^f: Permeability Index

Water quality indices

The sodium adsorption ratio (SAR) indicates relative proportion of sodium to calcium and magnesium, which influences soil physical properties especially hydraulic conductivity. Results indicated that 6 per cent of water samples have high (SAR > 18), 53 per cent with medium (SAR 10-18) and 41 per cent with low (SAR < 10) sodium hazard. Also, soluble sodium in irrigation water is an important parameter influencing the soil properties and crop performance. High concentration of sodium in irrigation water may stunt the plant growth and reduces soil permeability (Joshi *et al.* 2009). The soluble sodium percentage (SSP) varied from 19.74 to 71.54 per cent and 17 per cent of water samples are unsafe for irrigation with SSP > 60 per cent.

The concentration of HCO_3^- and CO_3^{2-} influences the suitability of water for irrigation purpose. The water with high residual sodium carbonate (RSC) will increase the pH in soils. Since the calcium and magnesium content were proportionately high, effect of HCO_3^- and CO_3^{2-} through RSC index is low as the RSC varied from -89 to -5 (Table 3). Potential salinity (PS) is an indicator of ability of water to cause salinity in soils and the suitability of water for safe use in different textured soils. PS varied from 7 to 40 me L^{-1} and the groundwater is unsuitable for irrigating fine textured soils (PS > 3). However, 71% samples are suitable for medium textured soils (PS 3 – 15 me L^{-1}) and 84 per cent suitable for sandy soils.

Generally calcium and magnesium maintain a state of equilibrium in most waters. High level of Mg^{2+} usually promotes increase in Na^+ concentration in irrigated soils. Results showed that 80 per cent of water samples are above the acceptable limit of 50 per cent MH (Ayers and Westcot, 1985). The Mg/Ca ratio for analyzed water samples varied from 0.36 to 3.18. Among the groundwater samples 73 per cent is safe (Mg/Ca < 1.5), 20 per cent is moderately safe (Mg/Ca 1.5-3.0) and 7 per cent is unsafe (Mg/Ca > 3.0) for irrigation. According to U.S. Salinity Laboratory (USSL, 1954) classification, 29 per cent are grouped in C3S1, 39 per cent in C3S2 and 2 per cent in C2S2 (Fig. 2) indicating their unsuitability for long term irrigation with moderate to high salinity and sodium hazard.

Evaluation of groundwater quality for irrigation use

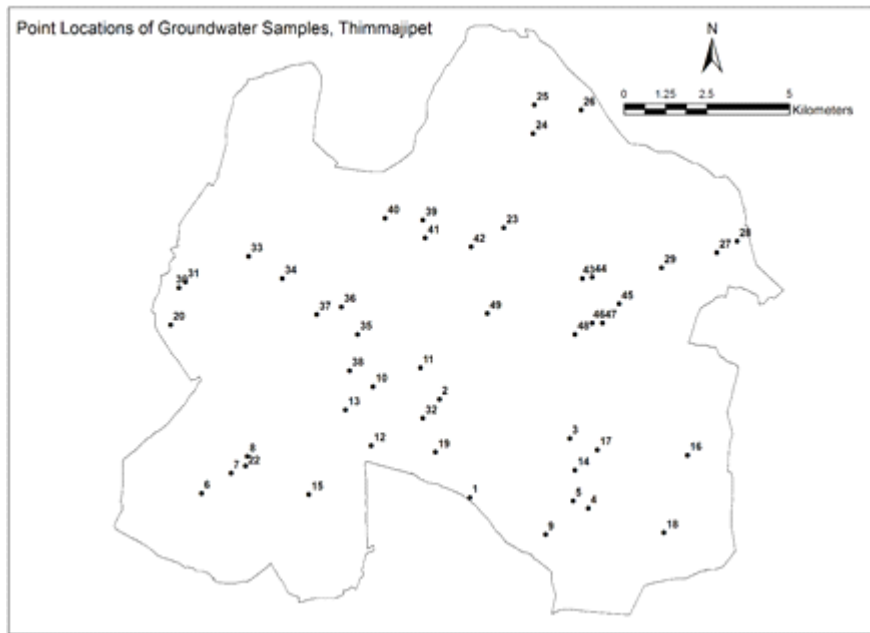


Fig. 1. Map showing point locations of collected groundwater samples in study area

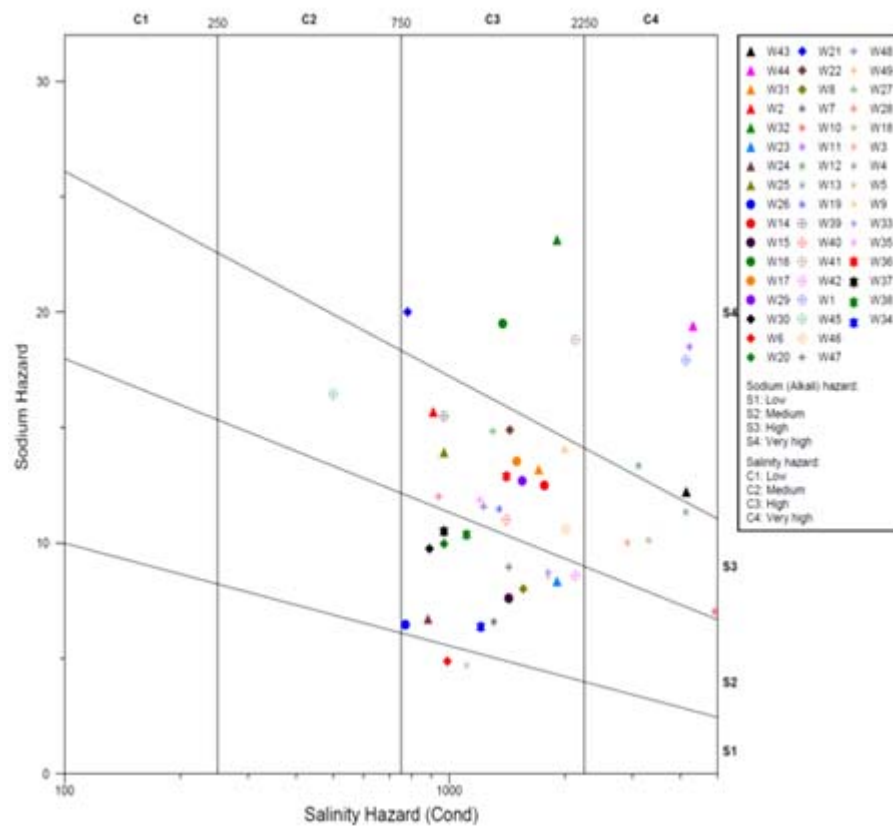


Fig. 2. Salinity diagram showing the classification of groundwater samples

CONCLUSION

The groundwater samples of Thimmajipet mandal were moderate to high in sodium hazard, highly saline and medium in chloride toxicity. The ground water is dominated by Na⁺, Mg²⁺ and Ca²⁺ and have the potential to cause damage to the cultivated crops by inducing soil salinity and alkalinity. Since most of the water samples were classified as highly saline, use of groundwater blended with fresh water for irrigation could be an option to minimize the potential of soil salinity. Upon long term use for irrigation the sodium dominated waters may force the accumulation of sodium in soils and may impede the hydraulic properties of soils. Hence, leaching methods need to be improvised to remove salts from irrigated soils.

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EFFECT OF FOLIAR NUTRITION IN AMELIORATING DROUGHT TOLERANCE AND YIELD IN GROUNDNUT

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ABSTRACT

A field experiment was conducted at Dryland Farm of S.V. Agricultural College, Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Tirupati during *rabi* season, 2014-15. The study aimed to enhance drought tolerance and yield through foliar nutrition in groundnut crop under moisture stress conditions. In the present study, twelve treatments were imposed which include ten foliar nutrient sprays and one irrigated and one moisture stress control. The results revealed that, significant variations for morphological, physiological and yield parameters were observed. Among the foliar spray treatments NPK- 19:19:19 @ 0.5%, KNO₃ @ 0.5% and KCl @ 1% at 60 DAS were recorded high chlorophyll content, high SPAD Chlorophyll Meter Reading (SCMR) values, moderate specific leaf area (SLA), moderate chlorophyll stability index (CSI), and low relative injury (RI) under moisture stress conditions. Foliar spray treatments NPK- 19:19:19 @ 0.5% recorded significantly highest pod yield (2335 kg ha⁻¹) followed by KNO₃ @ 0.5% (2190 kg ha⁻¹) and KCl @ 1% (2154 kg ha⁻¹).

KEYWORDS: Groundnut, Moisture stress, Nutrients, Foliar application

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the world's most chief protein rich vegetable oilseed legume crops. It is an important oil and protein source to a large portion of the population in Asia, Africa and the America. Major groundnut producing countries are China, India, Nigeria, USA, Indonesia, Argentina, Sudan, Senegal and Myanmar.

In India, groundnut occupies an area of 5.5 M ha producing 9.6 M t and with a productivity of 1750 kg ha⁻¹ in India (National Research Center for Groundnut Annual report, 2014). Groundnut in Andhra Pradesh is cultivated in an area of 1.6 m ha during rainy season (*khari*) and 0.3 m ha in post rainy season (*rabi*). Rayalaseema zone of Andhra Pradesh (Chittoor, Kurnool, Kadapa and Anantapur) is a predominant groundnut growing region where more than 70 per cent area falls under rainfed condition. Hence, the productivity of groundnut in Andhra Pradesh is low (650 kg ha⁻¹).

Drought, a complex combination of stresses, involves both moisture stress and high temperature stress. Water is one of the major environmental factors influencing almost all aspects of plant growth and metabolism (Kramer, 1983). Different approaches were used to reduce the damage caused by drought such as selection of plants

for higher water use efficiency, use of different growth regulators (GA₃, IAA and Cytokinines), seed treatment with osmoprotectants (Muna *et al.*, 2013), foliar application of one per cent KCl (Aboelill, 2012.), exogenous application of organic compounds such as amino acids (Ardebili *et al.*, 2012) etc.

Foliar feeding of fertilizers has been used as a means of supplying supplemental doses of minor and major nutrients, plant hormones, stimulants and other beneficial substances to plants. Observed effect of foliar fertilization have included yield increase, diseases and insect pest resistance, improved drought tolerance, and enhanced crop quality. Plant response is dependent on species, forms of fertilizer, concentration and frequency of application of nutrients (Anonymous, 1985).

Foliar-applied nutrients have indirect use for enhancement of stress resistance mechanism in field crops. Foliar application of key nutrients like Phosphorous (P), Potassium (K), Calcium (Ca), Zinc (Zn) and Boron (B) alleviates these deficiencies and increases drought tolerance by maintaining key physiological processes. Potassium (K) has the major role in osmo-regulation, photosynthesis, transpiration, stomatal opening and closing and synthesis of protein etc (Milford and Johnston, 2007). Hence, foliar fertilization can help in mitigating drought stress. Thus the objective of the present study

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was to know the physiological efficiency of foliar application of nutrients and enhancing yield and drought tolerance in groundnut under moisture stress conditions.

MATERIAL AND METHODS

A field experiment was conducted at S.V. Agricultural College Farm, Tirupati campus of Acharya N.G. Ranga Agricultural University, during *rabi* season, 2014-15 which is geographically situated at 13.5°N latitude and 79.5°E longitude, with an altitude of 182.9 m above the mean sea level in the Southern Agro-Climatic Zone of Andhra Pradesh. Groundnut variety 'Dharani' was selected for the study whose duration was 110 days. The experiment was laid out in a Randomized block design with 12 treatments replicated thrice. The following treatments were foliar applied at 60 days after sowing (15 days after imposition of moisture stress). Treatments consists of T₁ - Control (Irrigated), T₂ - Control (Stress), T₃- Water spray, T₄- 2 % Urea, T₅- 2 % Di Ammonium Phosphate (DAP), T₆ - 1 % KCl, T₇ - 0.5 % ZnSO₄, T₈- 0.5 % FeSO₄, T₉ - 1 % Urea + 0.5 % Zn SO₄ + 0.5 % FeSO₄ , T₁₀- NPK 19:19:19 @ 0.5 % (water soluble fertilizers), T₁₁- NPK 17:17:17 @ 0.5 % (water soluble fertilizers) and T₁₂ - Potassium Nitrate @ 0.5 %.

The experiment was conducted in a sandy loam soil with a plot size of 3 x 3 m. The crop was sown on 18th December, 2014 with a spacing of 22.5 X 10 cm. Nitrogen was applied as basal dose @ 20 kg N ha⁻¹ in the form of urea. Phosphorus and potash were given @ 40 kg P₂O₅ and 50 kg K₂O per ha basally. Gypsum was applied at 35 DAS @ 500 kg ha⁻¹. Hand weeding and hoeing was done twice at 20 days interval after sowing. Prophylactic measures were taken up to protect the crop from all insect pest and diseases throughout the crop growth period. Need based irrigations were given, however, the crop was irrigated to field capacity at 40 DAS and then there was no irrigation provided between 45-75 DAS. Treatments were foliar applied on 60th day after sowing *i.e.* 15 days after imposition of moisture stress.

Data was recorded on water use efficiency (WUE) traits, heat tolerance traits at 75 DAS (15 days after foliar nutrition) and yield parameters under moisture stress condition. Specific leaf area (SLA) was computed by following formula as SLA = A /WL (Where A = Leaf area; WL = Leaf dry weight at time t). The SCMR was measured for all four leaflets of third leaf from the top of the main axis using SPAD meter of Minolta company, NJ, USA (SPAD 502).

Relative injury per cent was measured using third leaf from top of respective plants.

Cell membrane integrity is tested by exposing leaves to high temperature and computing relative injury to the membranes in terms of electrolytes leakage. Relative injury per cent was measured using third leaf from top of the plant. The method used for measuring membrane damage was similar to the method given by Leopald *et al.* (1981).

$$\text{Per cent leakage (\%)} = \frac{I_a}{F_a} \times 100$$

where, I_a: Initial absorbance, F_a :Final absorbance.

Chlorophyll stability index CSI (%) was measured using third leaf from top of respective groundnut genotypes. Fresh leaf sample (0.1 g) was collected from the selected groundnut genotypes and placed in a 100 ml flask and heated it in a water bath for 60 min at 65°C. 10 ml of DMSO solution was added to treated and untreated samples. Respective checks samples are also maintained without imposing heat treatment. Both treated and untreated conical flasks were kept for overnight and the concentration of total chlorophyll is quantified by reading the optical density at 663nm and 645nm.

$$\text{Total Chl mg g}^{-1} = \frac{20.02 (D645) + 8.02 (D663) \times V}{1000 \times W}$$

The CSI of the leaf sample was calculated using the following formula

$$\text{CSI\%} = \frac{\text{Total chlorophyll of the heated sample}}{\text{Total chlorophyll of unheated sample}} \times 100$$

RWC is a reliable drought avoidance parameter adopted by plants. Leaflets were collected from the third leaf from the top of the primary branch of each genotype, and are floated in water for 6 hours and allowed to gain turgidity. Turgid weights are recorded and dried in hot air oven at 80°C to a constant weight to record dry weight. RWC is estimated and expressed in per cent using the following formula.

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

The data on seed yield and yield components were recorded at the time of harvest. The data were statistically analyzed as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The results of present investigation revealed existence of sufficient treatment variability among the treatments tested for WUE, thermotolerance and other traits *viz.*, chlorophyll content and RWC. The data pertaining to plant height, WUE, thermotolerance and other traits at 75 DAS in response to foliar spray treatments were mostly discussed and presented here.

Plant height (cm)

Data presented in Table 1 revealed that foliar spray treatment NPK-19:19:19 @ 0.5% recorded 22 per cent higher plant height followed by KNO₃ @ 0.5 % and KCl @ 1% with 21 and 20 per cent higher plant height compared to control stress treatment. Plant height and number of leaves plant⁻¹ were influenced by potassium spray and irrigation in both greengram varieties ML- 267 and LGG- 460. Maximum plant height was recorded by LGG- 460 with one per cent K₂SO₄ spray at vegetative stage followed by irrigation at 10 days after spray over complete drought (Rangamma and Naidu, 2006).

Specific leaf Area (SLA) (cm² g⁻¹)

The Specific Leaf Area (SLA) is often considered as an indirect measure of leaf density. Significantly higher values of specific leaf area recorded in all treatments. Data presented in Table 1 revealed that, control irrigated treatment recorded significantly 20 per cent highest SLA compared to control stress treatment. The foliar spray treatment NPK- 19:19:19 @ 0.5% and KCl @ 1% showed significantly higher SLA by 13 per cent followed by KNO₃ @ 0.5% spray (12 per cent) compared to control stress treatment. Higher SLA in these foliar spray treatments might be due to maintenance of higher chlorophyll content, leaf drymatter and higher photosynthetic rate due to the supply of the nutrients at critical stages (Pradeep and Elamathi, 2007; Zayed *et al.*, 2011).

SPAD chlorophyll meter readings (SCMR)

SPAD meter quantifies the greenness or relative chlorophyll content of leaves. The SPAD Chlorophyll Meter Reading (SCMR) is an indication of leaf nitrogen status, since SLN (Specific leaf nitrogen) determines the differences in WUE, it can be visualized that SCMR could

reflect well in WUE differences. Significant differences for SCMR were found among foliar spray treatments (Table 1). Control irrigated treatment showed 6 per cent higher SCMR compared to control stress treatment. Among the foliar spray treatments significant difference were recorded. NPK- 19:19:19 @ 0.5% showed 5 per cent high SCMR value followed by KCl @ 1% and KNO₃ @ 0.5% (4 per cent) compared to control stress treatment. The overall mean SCMR of rainfed condition (57.6) was significantly higher than overall mean in irrigated condition (47.4). This might be due to relatively less restricted leaf expansion and with relatively less chlorophyll formation under irrigated conditions (Kashiwagi *et al.*, 2006).

Relative membrane injury (RI) (%)

Relative membrane injury values were high in control stress treatments compared to control irrigated conditions. Data presented in Table 1 revealed that, control irrigated treatment recorded 50 per cent low relative injury compared to control stress treatment. Among the foliar spray treatments, NPK- 19:19:19 @ 0.5% and KNO₃ @ 0.5% showed significantly 30 and 29 per cent low RI compared to control stress treatment followed by KCl @ 1% with 26 per cent low RI. Relative injury increased with increase in temperature from 50 °C to 55 °C. This is because at lower temperature the RI was too low to cause substantial electrolyte leakage in a reasonable time (Talwar *et al.*, 2002).

Chlorophyll stability index (CSI) (%)

The chlorophyll stability index is an indication of the stress tolerance capacity of plants. This leads to increased photosynthetic rate, more dry matter production and higher productivity. Hence, a high CSI value means that the temperature stress did not have much effect on chlorophyll content of plants. Data presented in Table 1 revealed that, Among the foliar spray treatments to mitigate moisture stress, the foliar spray treatment KNO₃ @ 0.5% recorded significantly 26 per cent highest CSI, followed by NPK- 19:19:19 @ 0.5% and KCl @ 1 % with 25 per cent high CSI compared to control stress treatment. Chlorophyll stability index and ash content showed significant and positive correlation with pod yield under moisture stress conditions. This might be due to decrease in internal water content of protoplasm and loss of chlorophyll a:b ratio which might be the result of premature senescence of leaves (Reddy *et al.*, 2003).

Table 1. Effect of foliar application of nutrients on plant height (cm), physiological traits and yield of groundnut (var. Dharani) under moisture stress conditions.

S.No.	Treatments	At 75 DAS						At harvest	
		Plant height (cm)	SCMR	SLA (cm ² g ⁻¹)	RI (%)	CSI (%)	RWC (%)	Pod Yield (kg ha ⁻¹)	
1.	Control (Irrigated)	22.89	45.8	169.0	12.6	80.1	94.1	3149	
2.	Control (Stress)	16.82	43.2	141.3	22.1	55.2	60.8	1668	
3.	Water spray	18.67	44.4	146.5	19.9	60.2	65.6	1815	
4.	2% Urea	18.21	44.0	151.2	18.8	63.1	66.2	1700	
5.	2% DAP	19.12	44.6	149.9	18.7	64.2	65.1	1844	
6.	1% KCl	21.07	44.9	160.1	16.3	68.9	71.1	2154	
7.	0.2% ZnSO ₄	20.92	44.0	150.7	17.7	66.2	66.0	1903	
8.	0.5% FeSO ₄	19.34	44.2	147.8	18.2	63.1	67.2	1815	
9.	1% Urea + 0.2% ZnSO ₄ + 0.5% FeSO ₄	20.67	44.3	148.0	18.3	63.8	65.7	1885	
10.	N:P:K- 19:19:19 @0.5%	21.62	45.3	159.2	15.7	69.1	71.3	2335	
11.	N:P:K- 17:17:17 @ 0.5%	20.13	44.2	150.1	16.9	66.6	68.6	2048	
12.	0.5% KNO ₃	21.36	45.0	158.3	15.7	69.5	71.3	2190	
	Mean	20.07	44.49	152.7	17.6	65.8	77.96	2042	
	CD (P=0.05)	3.16	0.861	5.37	0.93	2.06	2.08	285	
	SEm ±	1.08	0.301	1.83	0.32	0.70	0.71	97	

Relative water content (RWC) (%)

The values of RWC are often considered as the appropriate measure of plant water status and considered to be the sensitive index of plant water content especially when plants are exposed to cellular water deficit conditions. Data presented in Table 1 revealed that, the foliar spray treatments NPK- 19:19:19 @ 0.5% and KNO₃ @ 0.5% recorded 15 per cent high RWC value followed by KCl @ 1% (14 per cent) compared to control stress treatment due to in groundnut, application of potassium improves relative water content of plants under normal as well as water stress conditions. The maintenance of plant water economy by potassium application in terms of high relative water content could be ascribed to the supposed role of potassium in stomatal resistance, water use efficiency and lowered transpiration rate (Umar and Moinuddin, 2002). This suggests that potassium has a positive role in turgidity maintenance and continual cell growth (Ardestani and Rad, 2012).

Pod yield (kg ha⁻¹)

Present data in Table 1 showed that, pod yield varied significantly among the treatments studied under moisture stress situation. Among the foliar spray treatments control irrigated treatment recorded 48 per cent higher pod yield compared to control stress treatment. Among foliar spray treatments, NPK- 19:19:19 @ 0.5% showed 38.5 per cent highest pod yield followed by KNO₃ @ 0.5% (36 per cent) and KCl @ 1% (31 per cent) compared to control stress treatment. Increase in groundnut yield may be cultivated under drought conditions along with potassium fertilization in order to minimize the adverse effects of water stress (Umar, 2006) and the increased yield may be due to the role of nitrogen fertilizer in increasing photosynthetic rate, synthesis of metabolites and translocation of assimilates to the seed as zinc is the activator of several enzymes in the plants (El Habbasha and Taha, 2008).

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PRICE VOLATILITY AND INTEGRATION OF MAJOR DRY CHILLI MARKETS

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ABSTRACT

A research study was conducted in five major chilli markets of India viz., Guntur, Khammam, Byadagi, Nagpur and Virudhunagar. Time series data on monthly prices were collected from 2000-01 to 2012-13 in each market. The market prices of chilli were found to be highly volatile. Johansen's Multiple Co-integration procedure indicated presence of at least four integration equations at 5 per cent level of significance. Hence markets are having long run equilibrium relationship. Guntur, Nagpur and Virudhunagar markets came to short run equilibrium. Granger causality test showed a bidirectional influence between Khammam and Byadagi; Nagpur and Virudhunagar and unidirectional influence between Guntur and Byadagi; Guntur and Khammam.

KEYWORDS: Granger causality test, integration, Johansen's Multiple Co-integration, Volatile

INTRODUCTION

India from time immemorial is the "Home of Spices" producing almost all the spices of the world. Among the 16 important spices cultivated in India chilli, which comes under the category of pungent spices is most widely cultivated not only in India but also in the world. India is one of the leading producers of chillies in the world and is the only country rich in many varieties with different quality factors. Even though chilli occupies major position in Indian spices, there were very limited studies conducted in India on prices and market integrations. Keeping in view the importance of chillies in Indian trade there is a need to analyze the behaviour of prices of chillies. Hence the present study was undertaken with the objectives of assessing price volatility in major chilli markets and extent of integration among the major markets of chillies in India.

MATERIAL AND METHODS

For the present study, five major chilli markets in India viz., Guntur and Khammam (A.P), Byadagi (Karnataka), Nagpur (Maharashtra) and Virudhunagar (Tamil Nadu) were selected. Time series data on monthly prices were collected from 2000-01 to 2012-13 in each market.

To assess the presence of volatility in chilli prices, ARCH-GARCH methodology was employed. Autoregressive Conditional Heteroscedasticity models are specially designed to model and forecast conditional variances. The variance of the dependent variable is

modeled as a function of past values of the dependent variable and independent or exogenous variables. ARCH models were introduced by the Engle (1982) and generalized as GARCH (Generalized ARCH) by Bollerslev (1986).

GARCH Model

Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model was originally proposed by Bollerslev. The simplest GARCH model is the GARCH (1,1) model, which can be written as:

$$\hat{\sigma}_t^2 = \hat{\alpha}_0 + \hat{\alpha}_1 u_{t-1}^2 + \hat{\alpha}_2 \hat{\sigma}_{t-1}^2$$

which says that the conditional variance of 'u' at time 't' depends not only on the squared error term in the previous time period but also on its conditional variance in the previous time period. This model can be generalized to a GARCH (p,q) model in which there are 'p' lagged terms of the squared error term and 'q' terms of the lagged conditional variances.

INTEGRATION TECHNIQUES

Augmented Dickey-Fuller test (ADF)

Before testing for integration among the selected markets, first, the price data series for all the markets selected were checked for its stationarity by employing Augmented Dickey-Fuller test (ADF). This test was conducted on the level and first differences of price series. The time series variables that are integrated, may be of

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Price volatility among major chilli markets

same order, while the unit root test finds out which variables are integrated of order one, or I(1). The following ADF regression equation was tested for stationarity

$$\Delta Y_t = \hat{a}_t + \hat{a}Y_{t-1} + \hat{a}_i + \sum_{i=1}^n \Delta Y_{t-1} + e_t$$

where, $\Delta Y_t = (Y_t - Y_{t-1})$; $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$

Y_t = vector to be tested for co-integration; t = time or trend variable; e_t = pure white noise error term

The null hypothesis that $\hat{a} = 0$; signifying unit root, states that the time series is non-stationary, while the alternative hypothesis $\hat{a} < 0$, signifies that the time series is stationary, thereby rejecting the null hypothesis.

(i) Johansen’s Multiple Co-integration test

To examine the price relation between two markets, the following basic relationship commonly used to test for the existence of market integration may be considered.

$$P_{it} = \hat{a}_0 + \hat{a}_1 P_{jt} + \hat{a}_t$$

where,

P_i = Price series of chilli in i th market; P_j = Price series of chilli in j th market.

\hat{a}_t = is the residual term assumed to be distributed identically and independently

\hat{a}_0 = represent domestic transportation costs, processing costs and sales taxes.

The test of market integration is straight forward if P_i and p_j are stationary variables.

Often, however, economic variables are non-stationary in which case the conventional tests are biased towards rejecting the null hypothesis.

For the present analysis, Johansen’s vector error correction model (VECM) was also used to study the short run and long run association for equilibrium among markets and to know the speed of adjustments among the markets for long run equilibrium.

(ii) Granger Causality Test

The Granger test is based on a premise that if forecasts of some variable, say X, obtained by using both the past values of X and the past values of another variable Y, is better than the forecasts obtained using past values of X alone, Y is then said to cause X,

$$Y_t = a_i Y_{t-i} + b_i X_{t-i} + e_i \dots\dots\dots (1)$$

$$X_t = c_i Y_{t-i} + d_i X_{t-i} + v_i \dots\dots\dots (2)$$

where, X_i and Y_i are two stationary time series with zero mean: e_i and v_i are two correlated series. Since the series of the variable are usually non-stationary and integrated of order I(1), first difference of the variable is normally taken which is stationary. The optimal lag length of the variables is determined by minimizing Akaike’s Information Criterion (AIC). Based on equations 1 and 2, unidirectional causation from one variable X to Y (i.e.

Table 1. Results of ARCH-GARCH analysis

Particulars	Guntur	Khammam	Byadagi	Nagpur	Virudhunagar
Alpha (α)	0.971419	0.93703	0.905577	0.968704	0.976871
Beta (β)	0.017555	0.269417	0.160154	0.401647	0.254125
$\alpha + \beta$	0.988974	1.206447	1.065731	1.370351	1.230996

Table 2. Results of multiple co-integration analysis for chilli domestic markets

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None *	0.2082	108.3931	88.80380	0.0010
At most 1 *	0.156333	72.91311	63.87610	0.0072
At most 2 *	0.129156	47.07357	42.91525	0.0182
At most 3 *	0.116263	26.05306	25.87211	0.0475
At most 4	0.046682	7.266573	12.51798	0.3175

Table 3. Results of vector error correction model for domestic chilli markets

Error Correction:	D(BYADAGI)	D(GUNTUR)	D(KHAMMAM)	D(NAGPUR)	D(VIRUDHUNAGAR)
CointEq1	-0.01273 (0.02862) [-0.44480]	0.106155 (0.03140) [3.38120]	0.030336 (0.02922) [1.03810]	0.065277 (0.02200) [2.96712]	-0.0726 (0.02803) [-2.59032]
D(BYADAGI(-1))	0.078176 (0.08890) [0.87942]	0.054654 (0.09753) [0.56041]	0.060120 (0.09078) [0.66230]	-0.0116 (0.06834) [-0.16977]	-0.06647 (0.08706) [-0.76340]
D(BYADAGI(-2))	0.174543 (0.08867) [1.96847]	-0.09197 (0.09728) [-0.94539]	0.345373 (0.09054) [3.81444]	0.061207 (0.06817) [0.89792]	-0.08973 (0.08684) [-1.03320]
D(BYADAGI(-3))	-0.05224 (0.09525) [-0.54841]	-0.03749 (0.10449) [-0.35881]	0.137457 (0.09726) [1.41328]	-0.0736 (0.07322) [-1.00518]	0.087688 (0.09329) [0.94000]
D(GUNTUR(-1))	0.059805 (0.08111) [0.73733]	-0.07285 (0.08898) [-0.81867]	-0.03816 (0.08282) [-0.46074]	0.112388 (0.06235) [1.80242]	0.112388 (0.06235) [1.80242]
D(GUNTUR(-2))	0.041905 (0.08199) [0.51110]	0.099019 (0.08995) [1.10084]	0.101740 (0.08372) [1.21520]	0.080943 (0.06303) [1.28419]	-0.01135 (0.08030) [-0.14128]
D(GUNTUR(-3))	0.149244 (0.07753) [1.92499]	0.119276 (0.08506) [1.40231]	0.107986 (0.07917) [1.36400]	0.043452 (0.05960) [0.72904]	-0.01234 (0.07593) [-0.16251]
D(KHAMMAM(-1))	-0.07203 (0.08699) [-0.82806]	-0.09798 (0.09543) [-1.02673]	0.003754 (0.08882) [0.04226]	0.154639 (0.06687) [2.31249]	0.051153 (0.08519) [0.60044]
D(KHAMMAM(-2))	-0.17149 (0.07978) [-2.14955]	0.026986 (0.08753) [0.30832]	-0.185 (0.08147) [-2.27083]	-0.07544 (0.06133) [-1.23004]	0.082874 (0.07814) [1.06062]
D(KHAMMAM(-3))	-0.11807 (0.08317) [-1.41967]	-0.15817 (0.09124) [-1.73350]	-0.01989 (0.08492) [-0.23418]	-0.02202 (0.06394) [-0.34442]	0.071347 (0.08145) [0.87593]
D(NAGPUR(-1))	0.162957 (0.11974) [1.36097]	0.598358 (0.13136) [4.55507]	0.166915 (0.12227) [1.36516]	0.344976 (0.09205) [3.74775]	0.147458 (0.11727) [1.25742]
D(NAGPUR(-2))	0.132298 (0.12777) [1.03540]	0.199916 (0.14018) [1.42615]	0.340868 (0.13048) [2.61249]	0.044271 (0.09823) [0.45069]	-0.15403 (0.12514) [-1.23087]
D(NAGPUR(-3))	0.082508 (0.12896) [0.63979]	0.254362 (0.14148) [1.79785]	-0.01912 (0.13169) [-0.14519]	-0.04892 (0.09914) [-0.49343]	0.019765 (0.12631) [0.15649]
D(VIRUDHUNAGAR (-1))	-0.05252 (0.09129) [-0.57529]	0.052326 (0.10016) [0.52243]	0.063966 (0.09323) [0.68614]	0.036044 (0.07018) [0.51356]	0.234112 (0.08941) [2.61827]
D(VIRUDHUNAGAR (-2))	0.098713 (0.09111) [1.08349]	-0.09136 (0.09995) [-0.91406]	-0.03377 (0.09303) [-0.36299]	-0.02905 (0.07004) [-0.41472]	0.148595 (0.08923) [1.66529]
D(VIRUDHUNAGAR (-3))	-0.01434 (0.09041) [-0.15856]	-0.04904 (0.09919) [-0.49440]	0.019154 (0.09232) [0.20747]	-0.05528 (0.06951) [-0.79532]	0.070485 (0.08855) [0.79599]
C	16.27637 (26.0262) [0.62538]	16.41182 (28.5530) [0.57478]	9.924598 (26.5765) [0.37343]	7.649964 (20.0080) [0.38234]	9.480301 (25.4901) [0.37192]
R-squared	0.2033	0.2780	0.3184	0.2913	0.2418

Table 4. Results of pair-wise granger causality tests of chilli domestic markets

Null Hypothesis:	Obs	F-Statistic	Prob.
GUNTUR does not Granger Cause BYADAGI BYADAGI does not Granger Cause GUNTUR	153	5.04888 1.45878	0.0023 0.2283
KHAMMAM does not Granger Cause BYADAGI BYADAGI does not Granger Cause KHAMMAM	153	3.44335 9.41364	0.0184 1.E-05
NAGPUR does not Granger Cause BYADAGI BYADAGI does not Granger Cause NAGPUR	153	5.58154 1.04906	0.0012 0.3728
VIRUDHUNAGAR does not Granger Cause BYADAGI BYADAGI does not Granger Cause VIRUDHUNAGAR	153	4.43250 0.10642	0.0052 0.9562
KHAMMAM does not Granger Cause GUNTUR GUNTUR does not Granger Cause KHAMMAM	153	2.75846 6.33758	0.0445 0.0005
NAGPUR does not Granger Cause GUNTUR GUNTUR does not Granger Cause NAGPUR	153	10.6878 2.03058	2.E-06 0.1122
VIRUDHUNAGAR does not Granger Cause GUNTUR GUNTUR does not Granger Cause VIRUDHUNAGAR	153	5.12596 1.83828	0.0021 0.1428
NAGPUR does not Granger Cause KHAMMAM KHAMMAM does not Granger Cause NAGPUR	153	8.39713 3.90286	3.E-05 0.0102
VIRUDHUNAGAR does not Granger Cause KHAMMAM KHAMMAM does not Granger Cause VIRUDHUNAGAR	153	4.46603 2.81725	0.0049 0.0412
VIRUDHUNAGAR does not Granger Cause NAGPUR NAGPUR does not Granger Cause VIRUDHUNAGAR	153	4.21451 4.34522	0.0068 0.0058

X Granger causes Y) is observed if the estimated coefficient on the lagged X variable in equation (1) is statistically non-zero as a group and the set of lagged Y coefficient is zero in equation (2). Similarly, unidirectional causation from Y to X (i.e. Y Granger causes X) is implied if the estimated coefficient on the lagged Y in equation (2) are statistically different from zero as a group and the set of estimated coefficient on the lagged X variable in equation (1) is not statistically different from zero. Feedback or mutual causality (bi-directional) would occur when the set of coefficients on the lagged X variable in equation (1) and on lagged Y variable in equation (2) are statistically different from zero. Finally, independence exists when the coefficients of both X and Y variables are equal to zero.

RESULTS AND DISCUSSION

The results of ARCH-GARCH analysis are presented in Table 1. The sum of Alpha and Beta indicates ARCH and GARCH effect for the given markets. The value close to one indicates persistence of shocks or volatility in the market.

From the results it could be inferred that barring Guntur and Byadagi, the prices in the remaining markets were highly volatile during the period from 2000-01 to 2012-13. Compared to all other markets, prices in Nagpur market exhibited more volatility with a value equal to 1.37 as indicated by sum of Alpha and Beta. Khammam and Virudhunagar were more or less closer regarding volatility. These results are in line with that of Ajjan *et al* (2012). Only in Guntur market, the value was close to

one (0.98) while in the remaining markets it was more than one.

Integration among Major Chilli Markets in India (2000-01 to 2012-13)

ADF test revealed that the price data series was non-stationary at level and became stationary after taking the first difference.

(i) Results of Co-integration Test

Johansen's Multiple Co-integration test conducted to study the long run integration among domestic markets indicated the presence of at least four co-integration equations at five per cent level of significance. Hence markets are having long run equilibrium. The results are presented in Table 2.

(ii) Results of Vector Error Correction Model (VECM)

From the results furnished in Table 3 it is clearly known that Guntur, Nagpur and Virudhunagar markets came to short run equilibrium as indicated by level of significance and the speed of adjustment was rapid. The prices of chilli in Khammam, Nagpur and Virudhunagar were influenced by their own monthly lags for long run equilibrium. Khammam market prices were influenced by two months lagged price of Byadagi market and Byadagi market prices were in turn influenced by Khammam market prices by two months lag. Also Khammam market influenced the prices of chilli in Nagpur market by one month lag and in turn prices in Khammam were influenced by two months lagged prices of Nagpur. One month lagged price of Nagpur influenced the prices in Guntur market. Thus it can be concluded that Khammam market prices were influenced by both Byadagi and Nagpur market prices.

(iii) Results of Granger Causality Test

From the results of Granger Causality test presented in Table 4 a bidirectional influence was observed between Khammam and Byadagi markets; Nagpur and Virudhunagar markets which implied that the chilli prices in Khammam were influenced by Byadagi and vice versa. Similarly Nagpur prices influenced Virudhunagar which in turn influenced Nagpur chilli prices. A unidirectional influence was observed between Guntur and Byadagi; Guntur and Khammam i.e. chilli prices in Guntur market influenced prices in Byadagi and Khammam markets. Also Byadagi market prices were influenced by Nagpur

and Virudhunagar. Both Guntur and Khammam chilli prices were influenced by Nagpur and Virudhunagar.

CONCLUSIONS

The study revealed that chilli prices in Khammam market of Andhra Pradesh was influenced by Byadagi market of Karnataka and vice-versa. The analysis further showed that Guntur and Khammam market chilli prices of Andhra Pradesh were influenced by Nagpur in Maharashtra and Virudhunagar in Tamil Nadu.

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YIELD AND ECONOMICS OF REDGRAM AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF POTASSIUM AND ZINC

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ABSTRACT

A field experiment conducted during *khariif*, 2014 at S.V. Agricultural College, dryland farm, Tirupati to know the soil and foliar application of potassium and zinc nutrition. The present study revealed that foliar application of 1% KNO_3 + 0.2% ZnSO_4 at flower bud initiation and pod formation stage along with RDF *i.e.* 20 kg N and 50 kg P_2O_5 ha^{-1} recorded significantly higher seed yield and economic returns. Foliar application of potassium and zinc was more effective than soil application. The lower values of yield and economics were recorded with application of recommended dose of fertilizers (20-50-0 kg N, P_2O_5 and K_2O ha^{-1}).

KEYWORDS: Economics, Potassium, Redgram, Yield and Zinc.

INTRODUCTION

Pulse crops play a significant role in food production in India, which accounts for one third of global area under pulses (25 million hectares) and one fourth of production (19.25 million tonnes) with a productivity of 694 kg ha^{-1} during the year 2013-14. Among pulses, pigeonpea is one of the important pulse crops as a major source of protein in the diets of large section of vegetarian population in the developing countries in general and India, in particular. The lower yield of pigeonpea in India is mainly attributed to its cultivation on poor soils with inadequate and imbalanced nutrient application. Application of plant nutrients in balanced proportion and appropriate quantities is absolutely essential for improving the productivity of pulses (Sarkar, 1995). Significance of nitrogen and phosphorus fertilization on pulses is well known, but the need for potassium and zinc nutrition and their combination at different stages is not well documented. Potassium is one of the major nutrients associated with movement of water, nutrients and carbohydrates within the plant. It not only enhances the biological nitrogen fixation, but also improves the protein content, water use efficiency and resistance to pests and diseases. Application of zinc improved the yield appreciably and foliar application of zinc is more economical in pulses.

MATERIAL AND METHODS

A field experiment was carried out during *khariif*, 2014 at S.V. Agricultural College, dryland farm, Tirupati.

The experimental soil was sandy loam in texture, neutral in reaction (pH 6.9), low in organic carbon (0.4%), available nitrogen (210.0 kg ha^{-1}), available phosphorus (14.2 kg ha^{-1}), available potassium (144.4 kg ha^{-1}) and zinc (1.07 kg ha^{-1}). The experiment was laid out in a randomized block design and replicated thrice with ten treatments which include recommended dose of fertilizers (RDF) *i.e.* 20 kg N and 50 kg P_2O_5 ha^{-1} in the form of urea and single super phosphate. Potassium and zinc were applied basally in the form of muriate of potash and ZnSO_4 . Foliar application of potassium and zinc in the form of KNO_3 @ 1.0 % and ZnSO_4 @ 0.2 % at flower bud initiation and pod formation stage. The redgram variety used in the present experiment was TRG-38, by adopting seed rate of 5 kg ha^{-1} and the crop was harvested on 11-02-2015. Chloropyrifos @ 2.5 ml l^{-1} of water was sprayed at flower bud initiation stage as a prophylactic measure against flower webber and thiodicarb @ 1 g l^{-1} of water was sprayed at pod formation stage to control pod borer (*Helicoverpa armigera*).

RESULTS AND DISCUSSION

The yield and economics of redgram was significantly influenced by soil and foliar nutrition of potassium and zinc. The highest seed and stalk yield of redgram was recorded with foliar application of 1% KNO_3 + 0.2% ZnSO_4 at flower bud initiation and pod formation stage along with RDF, which was significantly superior over the rest of the nutrient management practices tried (Table 1). The foliar application of 1% KNO_3 + 0.2%

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Table 1. Seed yield, stalk yield (kg ha⁻¹), harvest index (%), and economics of redgram as influenced by soil and foliar application of potassium and zinc

Treatments	Seed yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Harvest index (%)	Net returns (Rs. ha ⁻¹)	Benefit cost-ratio
T ₁ : Recommended dose of fertilizers (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	680	2403	22.05	1773	1.10
T ₂ : RDF + Soil application of 50 kg K ₂ O ha ⁻¹	1052	3649	22.38	11155	1.57
T ₃ : RDF + Soil application of 25 kg ZnSO ₄ ha ⁻¹	1065	3752	22.11	12200	1.62
T ₄ : RDF + Soil application of 50 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	1304	4531	22.35	17991	1.85
T ₅ : RDF + Foliar application of KNO ₃ @ 1% at flower bud initiation stage	800	2848	21.93	4767	1.25
T ₆ : RDF + Foliar application of KNO ₃ @ 1% at flower bud initiation and pod formation stage	1045	3613	22.43	11517	1.58
T ₇ : RDF + Foliar application of ZnSO ₄ @ 0.2% at flower bud initiation stage	887	3133	22.07	7939	1.43
T ₈ : RDF + Foliar application of ZnSO ₄ @ 0.2% at flower bud initiation and pod formation stage	1123	3888	22.42	14982	1.80
T ₉ : RDF + Foliar application of 1% KNO ₃ + 0.2% ZnSO ₄ at flower bud initiation stage	1257	4332	22.49	18437	1.96
T ₁₀ : RDF + Foliar application of 1% KNO ₃ + 0.2% ZnSO ₄ at flower bud initiation and pod formation stage	1478	5007	22.80	23774	2.16
SEm±	39.8	259.3	-	1196.5	0.06
CD(P=0.05)	117	764	-	3529	0.18

ZnSO₄ at flower bud initiation and pod formation stage along with RDF resulted in 117.3 per cent higher seed yield compared to recommended dose of fertilizers *i.e.* 20 kg N and 50 kg P₂O₅ ha⁻¹. The superiority of foliar nutrition in this nutrient management practice might be due to coincidence of foliar application with peak nutrient requirement of the crop, moreover peak absorption of potassium occurs from flowering to early pod development, any deficiency of potassium during this period can result in yield loss without obvious foliar symptoms. The quantity of nutrients absorbed due to soil application of potassium and zinc may not be sufficient to meet the crop demands at pod development stage. Supplementing the nutrients through foliage at flowering and pod formation stages might have resulted in better nutrient uptake and thereby regaining the photosynthetic efficiency of the plant at post anthesis period resulted in increased yield attributes and seed yield of redgram (Reddy *et al.*, 1991). Soil application of 50 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF and foliar application of 1% KNO₃ + 0.2% ZnSO₄ at flower bud initiation stage along with RDF were the next best nutrient management practices, which were comparable with each other. Application of recommended dose of fertilizers alone (20-50-0 kg N, P₂O₅ and K₂O ha⁻¹) recorded the lowest seed and stalk yield due to deficiency of potassium and zinc as the experimental soils, which are poor in available potassium (144.4 kg ha⁻¹) and available zinc (1.07 kg ha⁻¹). Similar results were also reported by Nalini *et al.* (2013) in blackgram.

The highest harvest index in redgram was recorded with foliar application of 1% KNO₃ + 0.2% ZnSO₄ at flower bud initiation and pod formation stage along with RDF. This might be due to better absorption and translocation of all the nutrients in a balanced proportion leading to increased partitioning of photosynthates from source to developing seed, where foliar application coincides with the peak crop nutrient demand and thereby maintenance of better source-sink relationship. The lowest harvest index was recorded with application of recommended dose of fertilizers due to poor source-sink relationship.

The highest net returns and benefit cost ratio were obtained with foliar application of 1% KNO₃ + 0.2% ZnSO₄ at flower bud initiation and pod formation stage along with RDF, which was significantly superior over other nutrient management practices. The increase in net returns might be due to increased seed yield and reduced cost of foliar application of potassium @ 1% and zinc sulphate @ 0.2% compared to soil application of 50 kg

K₂O and 25 kg zinc sulphate ha⁻¹. The next best treatment was soil application of 50 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF, which was however comparable with foliar application of 1% KNO₃ + 0.2% ZnSO₄ at flower bud initiation stage along with RDF. The lowest net returns and benefit cost ratio were obtained with application of recommended dose of fertilizers. These results are in accordance with the findings of Babu *et al.* (2012), Anitha *et al.* (2005) and Shivay *et al.* (2014).

In conclusion, the present study revealed that RDF *i.e.* 20 kg N and 50 kg P₂O₅ ha⁻¹ along with foliar application of 1% KNO₃ + 0.2% ZnSO₄ at flower bud initiation and pod formation stage resulted in increased seed yield and monetary returns in redgram on sandy loam soils of Southern Agroclimatic Zone of Andhra Pradesh.

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LONG-TERM EFFECT OF MANURE AND FERTILIZERS ON SOIL PHOSPHORUS FRACTIONS UNDER GROUNDNUT MONOCROPPING SYSTEM

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ABSTRACT

Status of soil phosphorus fractions under rainfed groundnut monocropping system was studied in a long-term field experiment during *Kharif*, 2014 being conducted at Regional Agricultural Research Station, Tirupati. The soil of experiment field was slightly acidic, non-saline, low in organic carbon and free CaCO_3 contents. The soil was low in available nitrogen, medium in phosphorus and medium to high in potassium. The micronutrients status of the experimental field was above critical levels. Inorganic P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P at 0-15 cm depth before sowing of the crop ranged from 20.43 to 37.62, 34.46 to 57.12, 16.97 to 31.31, 14.20 to 22.01, 27.25 to 54.50, 112.87 to 192.78, 27.00 to 45.00 mg kg^{-1} , respectively. At harvest the P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P at 0-15 cm depth ranged from 17.06 to 33.20, 31.87 to 53.31, 14.87 to 28.31, 10.62 to 20.25, 30.65 to 56.80, 105.40 to 180.52, 21.00 to 45.00 mg kg^{-1} , respectively. Similarly at 15-30 cm depth the inorganic P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P before sowing ranged from 16.91 to 31.90, 32.27 to 49.95, 15.92 to 25.06, 12.57 to 22.72, 25.25 to 51.25, 106.72 to 185.47, 27.00 to 41.00 mg kg^{-1} , respectively and at harvest, these ranged from 15.62 to 29.68, 30.00 to 47.50, 13.75 to 25.25, 14.25 to 20.56, 26.30 to 52.42, 101.97 to 175.77, 23.00 to 36.00 mg kg^{-1} , respectively.

KEYWORDS: Inorganic P fractions (Al-P, Fe-P, Occluded P and Ca-P), Organic P, Total P

Groundnut, (*Arachis hypogaea* L.) is the major oilseed cum cash crop for millions of small scale farmers in the semi-arid tropics. It is the world's 4th most important source of edible oil and 3rd most important source of vegetable proteins. The uses of groundnut are diverse as all parts of the plant could be used. The kernel is a rich source of edible oil, containing 36 to 54 per cent oil and 25 to 32 per cent protein. Groundnut can meet a major portion of its N requirement through biological N fixation. However, phosphorus deficiency has been identified as one of the major constraints in crop production. Phosphorus (P) is an essential major element for plant growth. Therefore, maintenance of an adequate amount of soil P through application of inorganic and/ or organic P is critical for the sustainability of cropping systems (Sharpley *et al.*, 1994). Phosphorus, like any other plant nutrient is present in soil in two major components *i.e.* organic and inorganic. Organic P, which is mainly confined to the surface layer, is mineralized into inorganic forms but, the plants mainly depend on inorganic P forms like saloid-P, Al-P, Fe-P and Ca-P fractions for their P requirements. The role of P in sustaining the crop growth in relation to its various P fractions has not been studied so far. Hence, the present investigation was taken up.

MATERIAL AND METHODS

A long term field experiment has been carried out at Regional Agricultural Research Station, Tirupati since 1981 laid out in Randomized Block Design, replicated four times with eleven treatments. The treatments include:

T₁ : Control (no manure and fertilizers), T₂ : Farm yard manure (FYM) @ 5 t ha⁻¹ (once in 3 years), T₃ : 20 kg Nitrogen (N) ha⁻¹, T₄ : 10 kg Phosphorus (P) ha⁻¹, T₅ : 25 kg Potassium (K) ha⁻¹, T₆ : 250 kg gypsum ha⁻¹, T₇ : 20 kg N + 10 kg P ha⁻¹, T₈ : 20 kg N + 10 kg P + 25 kg K ha⁻¹, T₉ : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum ha⁻¹, T₁₀: 20 kg N + 10 kg P + 25 kg K + 100 kg lime ha⁻¹, T₁₁ : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum + 25 kg ZnSO₄ ha⁻¹ (Once in three years). Hence, treatments with FYM, N, P, K and gypsum either alone or in combination with lime and zinc sulphate were imposed.

During *Kharif* 2014 the soil samples were collected before sowing and at harvest from 0-15 and 15-30 cm depth. Soil physico-chemical and available nutrients were analysed following the standard procedures laid down by Jackson (1973). Fractions of P were analysed as procedures described by Chang and Jackson (1957).

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Organic P by Saunders and Williams (1955) and total P by Olsen and Sommers (1982).

RESULTS AND DISCUSSION

Physico-chemical properties of experimental site

The experimental field was slightly acidic with pH ranging from 5.26 to 5.71, non-saline, low in organic carbon (0.30 to 0.48 %) and free CaCO₃ (0.22 to 0.47 %) contents. The available nitrogen was low (148 to 205 kg ha⁻¹), P was medium (27 to 45 kg ha⁻¹) and K was medium to high (218 to 409 kg ha⁻¹). The secondary nutrients *viz.*, Ca, Mg and S ranged from 2.35 to 4.35, 1.85 to 2.67 C mol (P⁺) kg⁻¹, and 7.5 to 12.2 mg kg⁻¹, respectively. The micronutrients status of the experimental field was above critical levels (Table 1).

Inorganic P fractions at 0-15 cm depth

Before sowing the highest value of Al-P was recorded in T₁₁ (37.62 mg kg⁻¹) and the lowest value in T₁ (20.43 mg kg⁻¹). The highest value of Fe-P was recorded in T₁₁ (57.12 mg kg⁻¹) and the lowest in T₁ (34.46 mg kg⁻¹). Similarly, the Occluded-P content was highest in T₁₁ (31.31 mg kg⁻¹) and the lowest in T₁ (16.97 mg kg⁻¹). The Ca-P was highest in T₉ (22.01 mg kg⁻¹) and the lowest in T₁ (14.20 mg kg⁻¹). However, the organic P content was highest in T₂ (54.50 mg kg⁻¹) and the lowest in T₃ (27.25 mg kg⁻¹). The highest value of total P content was recorded in T₁₁ (192.78 mg kg⁻¹) and the lowest in T₄ (112.87 mg kg⁻¹). The available P content was lowest (27.00 mg kg⁻¹) in T₆ and the highest in T₁₁ (45.00 mg kg⁻¹).

At harvest, Al-P content was highest in T₁₀ (33.20 mg kg⁻¹) and the lowest in T₁ (17.06 mg kg⁻¹). The highest value of Fe-P was noticed in T₁₀ (53.31 mg kg⁻¹) and the lowest in T₄ (31.87 mg kg⁻¹). Occluded P content was noticed highest in T₁₀ (28.31 mg kg⁻¹) and the lowest in T₁ (14.87 mg kg⁻¹). The highest Ca-P content was recorded in T₉ (20.25 mg kg⁻¹) and the lowest in T₆ (10.62 mg kg⁻¹). Whereas, the organic P content was highest in T₂ (56.80 mg kg⁻¹) and the lowest in T₃ (30.65 mg kg⁻¹). Total P content was highest in T₁₁ (180.52 mg kg⁻¹) and the lowest in T₄ (105.40 mg kg⁻¹). However, highest available P content was recorded in T₁₁ (45.00 mg kg⁻¹) and the lowest (21.00 mg kg⁻¹) in T₁ (Table 2 and 3).

Inorganic P fractions at 15-30 cm depth

Before sowing the Al-P and Occluded P content were highest in T₁₁ (31.90 and 27.02 mg kg⁻¹) and the lowest in T₁ (16.91 and 15.92 mg kg⁻¹), respectively. Fe-P content

was also highest in T₁₁ (49.95 mg kg⁻¹) but lowest in T₄ (32.27 mg kg⁻¹). The highest Ca-P content was noticed in T₉ (22.72 mg kg⁻¹) and the lowest in T₁ (12.57 mg kg⁻¹). Whereas, the organic P content was recorded highest in T₂ (51.25 mg kg⁻¹) and the lowest in T₃ (25.25 mg kg⁻¹). The highest total P content was recorded in T₁₁ (185.47 mg kg⁻¹) and the lowest in T₄ (106.72 mg kg⁻¹). The available P was highest in T₁₁ (41.00 mg kg⁻¹) and the lowest (27.00 mg kg⁻¹) both in T₁ and T₄ (Table 4 and 5).

Similar trend was observed at harvest stage also. The Al-P and Occluded P content were highest in T₁₀ (29.68 and 25.25 mg kg⁻¹) and lowest in T₁ (15.62 and 13.75 mg kg⁻¹), respectively. However, Fe-P content was highest in T₁₀ (47.50 mg kg⁻¹) and the lowest in T₄ (30.00 mg kg⁻¹). Ca-P content was recorded highest in T₉ (20.56 mg kg⁻¹) and the lowest in T₄ (14.25 mg kg⁻¹). Similarly, organic P content was highest in T₂ (52.42 mg kg⁻¹) and the lowest in T₃ (26.30 mg kg⁻¹) and total P content was recorded in T₁₁ (175.77 mg kg⁻¹) and the low in T₄ (101.97 mg kg⁻¹). Whereas, available P content was recorded high in T₆ (36.00 mg kg⁻¹) and the low in T₁ (23.00 mg kg⁻¹).

The results revealed that all the P fractions were low in sub-soil (15-30 cm depth) compared to surface soil samples. Such results were reported earlier for Al-P and Fe-P by Kalaivanan and Sudhir (2012) and attributed for lower amounts of Al₂O₃ content at lower depths. The high Fe-P content in surface soil was attributed to release of organic acids due to decomposition of organic matter, which resulted in precipitation of Fe-P. In this particular experiment, the source of organic matter might be the leaf fall during crop growth except in T₂ where FYM was added. More or less, the same trend was observed in case of O-P, total P, available P and Ca-P, but for Ca-P slightly higher value was noticed at harvest in 15-30 cm depth.

Significant variations were noticed with respect to P-fractions among the treatments both before and after harvest of groundnut crop. The lowest values was observed in control plot for Al-P, Fe-P, Occluded P, and Ca-P while the total-P, organic-P and available-P were lowest in treatments T₄, T₃ and T₆, respectively at 0-15 cm depth of soil.

Similarly the P-fractions *viz.*, Al-P, Fe-P, Occluded-P, Ca-P, organic-P and total-P significant among treatments but the available-P was non-significantly influenced by treatment at 15-30 cm depth both at before sowing and after harvest of the crop.

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Table 1. Soil physico-chemical properties, available nutrients and micronutrient status of experimental field before sowing as influenced by long-term application of manure and fertilizers

Treatments	pH	Electrical conductivity (dS m ⁻¹)	Organic carbon (%)	Free calcium carbonate (%)	Nitrogen (N)	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)	mg kg ⁻¹			
								Fe	Mn	Cu	Zn
T ₁ : Control	5.7	0.06	0.30	0.41	148	28	218	16.98	38.59	0.87	0.99
T ₂ : FYM @ 5 t ha ⁻¹	5.6	0.07	0.48	0.47	187	43	302	14.55	39.64	0.80	1.01
T ₃ : N @ 20 kg ha ⁻¹	5.4	0.07	0.43	0.27	169	37	291	16.94	35.38	0.83	0.66
T ₄ : P @ 10 kg ha ⁻¹	5.4	0.06	0.40	0.36	172	31	343	14.40	36.41	0.94	0.79
T ₅ : K @ 25 kg ha ⁻¹	5.4	0.06	0.32	0.46	148	44	313	14.87	39.13	0.79	0.88
T ₆ : G @ 250 kg ha ⁻¹	5.4	0.08	0.30	0.22	156	27	376	17.43	40.09	0.94	1.04
T ₇ : NP	5.3	0.08	0.35	0.27	176	37	401	18.20	40.38	0.83	0.65
T ₈ : NPK	5.3	0.10	0.30	0.32	191	45	310	20.65	41.28	0.80	0.78
T ₉ : NPK+G	5.3	0.10	0.39	0.25	166	44	270	19.69	40.84	0.82	0.66
T ₁₀ : NPK+L	5.4	0.08	0.38	0.34	182	44	385	19.81	37.95	0.77	0.96
T ₁₁ : NPK+G+ZnSO ₄	5.3	0.09	0.36	0.33	205	45	409	15.32	42.70	0.93	1.32
GM	-	0.08	0.36	0.34	172	40	328	17.16	39.30	0.84	0.88
SEm±	0.1	0.01	0.04	0.02	12.2	2.8	12.4	3.57	9.15	0.08	0.06
CD (P=0.05)	NS	NS	NS	0.05	35.1	8.2	35.7	NS	NS	NS	0.18

G: Gypsum; L: Lime @ 100 kg ha⁻¹, ZnSO₄@ 25 kg ha⁻¹

Table 2. Soil Al-P, Fe-P, Ca-P and occluded-P (mg kg⁻¹) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (0-15 cm depth)

Treatments	Al-P		Fe-P		Occluded P		Ca-P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T ₁ : Control	20.43	17.06	34.46	37.50	16.97	14.87	14.20	17.87
T ₂ : FYM @ 5 t ha ⁻¹	35.96	25.18	49.33	47.18	29.40	21.18	20.20	15.43
T ₃ : N @ 20 kg ha ⁻¹	27.62	23.43	46.88	43.43	20.87	16.87	17.13	13.55
T ₄ : P @ 10 kg ha ⁻¹	27.45	21.87	42.58	31.87	21.70	19.06	17.81	12.07
T ₅ : K @ 25 kg ha ⁻¹	26.10	19.25	48.07	45.62	18.88	15.87	16.62	13.62
T ₆ : G @ 250 kg ha ⁻¹	26.63	20.50	41.45	35.00	20.76	17.75	19.01	10.62
T ₇ : NP	28.56	28.43	45.58	43.12	23.70	24.31	19.70	15.63
T ₈ : NPK	29.40	24.68	55.68	48.12	21.43	18.75	18.03	16.18
T ₉ : NPK+G	33.83	30.62	50.40	48.75	24.58	24.56	22.01	20.25
T ₁₀ : NPK+L	32.62	33.20	52.52	53.31	27.27	28.31	19.97	16.37
T ₁₁ : NPK + G + ZnSO ₄	37.62	33.00	57.12	51.18	31.31	24.62	21.43	18.58
GM	29.65	25.20	47.64	44.09	23.35	20.55	18.73	15.84
SEm±	1.07	1.08	1.53	1.18	1.23	0.73	0.70	0.66
CD (P=0.05)	3.08	3.12	4.42	3.41	3.56	2.13	2.02	1.92

G: Gypsum; L: Lime @ 100 kg ha⁻¹, ZnSO₄ @ 25 kg ha⁻¹

Table 3. Soil organic-P, total-P and available-P (mg kg⁻¹) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (0-15 cm depth)

Treatments	Organic P		Total P		Available P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T ₁ : Control	40.75	43.08	131.86	127.08	28.00	21.00
T ₂ : FYM @ 5 t ha ⁻¹	54.50	56.80	175.47	164.81	43.00	35.00
T ₃ : N @ 20 kg ha ⁻¹	27.25	30.65	167.97	156.17	37.00	31.00
T ₄ : P @ 10 kg ha ⁻¹	43.00	45.06	112.87	105.40	31.00	24.00
T ₅ : K @ 25 kg ha ⁻¹	39.25	38.82	170.00	166.13	44.00	35.00
T ₆ : G @ 250 kg ha ⁻¹	34.25	37.51	140.32	131.27	27.00	23.00
T ₇ : NP	51.00	53.65	160.41	158.65	37.00	30.00
T ₈ : NPK	35.50	42.81	188.11	168.98	45.00	44.00
T ₉ : NPK+G	48.75	53.08	176.03	167.22	44.00	40.00
T ₁₀ : NPK+L	47.50	51.07	180.41	170.83	44.00	44.00
T ₁₁ : NPK+G+ZnSO ₄	42.22	44.25	192.78	180.52	45.00	45.00
GM	42.25	45.16	163.29	154.27	40.00	33.80
SEm±	0.89	0.93	8.19	5.46	2.80	3.40
CD (P=0.05)	2.57	2.71	23.67	15.79	8.20	9.90

G: Gypsum; L: Lime @ 100 kg ha⁻¹, ZnSO₄ @ 25 kg ha⁻¹

Table 4. Soil Al-P, Fe-P, Ca-P and occluded-P (mg kg⁻¹) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (15-30 cm depth)

Treatments	Al-P		Fe-P		Occluded P		Ca-P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T ₁ : Control	16.91	15.62	39.60	35.75	15.92	13.75	12.57	18.62
T ₂ : FYM @ 5 t ha ⁻¹	27.71	22.50	45.25	41.87	25.06	19.75	19.35	17.81
T ₃ : N @ 20 kg ha ⁻¹	25.20	21.25	42.31	40.00	19.33	15.50	16.82	14.88
T ₄ : P @ 10 kg ha ⁻¹	27.33	19.06	32.27	30.00	19.96	18.06	18.92	14.25
T ₅ : K @ 25 kg ha ⁻¹	21.92	18.37	43.92	41.87	17.97	15.50	15.76	15.50
T ₆ : G @ 250 kg ha ⁻¹	22.90	19.37	37.63	34.06	18.88	16.75	18.88	14.37
T ₇ : NP	25.75	26.56	41.06	39.16	21.07	18.81	19.58	17.25
T ₈ : NPK	24.58	22.50	48.07	44.06	23.45	19.06	20.26	17.00
T ₉ : NPK+G	31.32	27.81	45.33	45.62	24.33	23.00	22.72	20.56
T ₁₀ : NPK+L	28.57	29.68	47.07	47.50	22.20	25.25	16.62	18.18
T ₁₁ : NPK +G + ZnSO ₄	31.90	28.12	49.95	45.93	27.02	20.00	21.07	19.37
GM	25.82	22.80	42.95	40.52	21.38	18.67	18.41	16.69
SEm±	0.79	0.50	1.12	0.91	0.93	0.90	0.75	0.62
CD (P=0.05)	2.30	1.44	3.25	2.63	2.69	2.62	2.17	1.79

G: Gypsum; L: Lime @ 100 kg ha⁻¹, ZnSO₄ @ 25 kg ha⁻¹

Table 5. Soil organic-P, total-P and available-P (mg kg⁻¹) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (15-30 cm depth)

Treatments	Organic P		Total P		Available P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T ₁ : Control	33.00	40.60	116.83	111.42	27.00	23.00
T ₂ : FYM @ 5 t ha ⁻¹	51.25	52.42	170.96	159.95	33.00	27.00
T ₃ : N @ 20 kg ha ⁻¹	25.25	26.30	157.28	148.26	32.00	28.00
T ₄ : P @ 10 kg ha ⁻¹	41.00	44.70	106.72	101.97	27.00	33.00
T ₅ : K @ 25 kg ha ⁻¹	37.00	35.50	161.50	163.15	31.00	28.00
T ₆ : G @ 250 kg ha ⁻¹	32.00	34.70	131.13	125.17	28.00	36.00
T ₇ : NP	48.00	50.63	155.83	152.71	31.00	31.00
T ₈ : NPK	38.25	40.06	177.26	166.40	40.00	33.00
T ₉ : NPK+G	46.50	48.95	173.02	166.16	40.00	31.00
T ₁₀ : NPK+L	44.25	48.12	175.67	167.56	40.00	27.00
T ₁₁ : NPK+G+ZnSO ₄	39.75	42.00	185.47	175.77	41.00	33.00
GM	39.65	42.18	155.60	148.95	33.63	30.00
SEm±	0.84	0.59	5.32	6.83	6.31	5.50
CD (P=0.05)	2.43	1.70	15.38	19.74	NS	NS

G: Gypsum; L: Lime @ 100 kg ha⁻¹, ZnSO₄ @ 25 kg ha⁻¹

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RESOURCE USE EFFICIENCY IN MAIZE CULTIVATION– DATA ENVELOPMENT ANALYSIS APPROACH

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ABSTRACT

DEA model was employed to analyze the resource use efficiency in maize cultivation. The findings revealed that, the number of farms operating at CRS are more in number in other farms (44%) followed by marginal (29.51%) and small farms (29.41%). Similarly, regarding the number of farmers operating at VRS, the other farms are again more in number with 72 per cent followed by small (47.06%) and marginal farms (44.27%). With reference to scale efficiency, again other farms dominate the scenario with 64 per cent followed by marginal (54.09%) and small farms (52.94%). At pooled level, 18.33 per cent of the farms are being operated at CRS with an average technical efficiency score of 0.6241 i.e., 22 out of 120 farms. Majority of the farmers (62.50%) are operating at IRS and only 25 per cent of the farmers are operating at DRS. This signifies that, more resources should be provided to these farms operating at IRS and the same should be decreased towards the farms operating at DRS. 12.5 per cent of the farms are operating at CRS indicating efficient utilization of resources. Log linear regression model was used to analyze the major determinants of input use efficiency of maize farms. Irrigation cost and fertilizer cost are the major determinants of maize farms across all the farmer categories and even at pooled level. In view of their positive influence on the CRS, it is essential to strengthen modern irrigation infrastructure like drip irrigation and offer more fertilizer subsidies to the farmer to enhance the crop production on cost-effective basis. It was also found that, the sample farmers are spending huge amount on applying chemical (carbofuran 3G) and fertilizers and hence, it is advocated to adopt INM, so as to ensure both cost effective and quality production of maize.

KEYWORDS: Maize, Resource use efficiency, Data envelopment analysis model

Maize is grown throughout the year in India. It is predominantly a kharif crop with 85 per cent of the area under cultivation during 2013-14. Maize is the third most important cereal crop in India after rice and wheat. It accounts for nearly nine per cent of total food grain production in the country. Maize in India, contributes nearly 9 per cent in the national food basket. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. The maize is cultivated throughout the year in all states of the country (Table: 1) for various purposes including grain, fodder, green cobs, sweet corn, baby corn, pop corn etc. The predominant maize growing states that contributes more than 80% of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%), Himachal Pradesh (4.4%). Apart from these States, maize is also

grown in Jammu and Kashmir and North-Eastern states. Maize has emerged as important crop in the non-traditional regions i.e. peninsular India as the state like Andhra Pradesh which ranks 5th in area (0.79 m.ha) has recorded the highest production (4.14 m.tonnes) and productivity (5.26 t ha⁻¹) in the country although the productivity in some of the districts of Andhra Pradesh is more or equal to the USA. Area under hybrid seeds in 2013-14 is estimated to be around 60 per cent of the total area under maize cultivation. Andhra Pradesh has the highest productivity followed by Tamil Nadu due to majority of the area being covered under Single Cross Hybrids (SCH).

Among the cereal crops in India, maize with an annual production of around 22.5 m. tonnes from 8.67 m.ha ranked third in production and contributes to 2.40 per cent of world production with almost five per cent share in world's harvested area in 2013-2014. In Andhra Pradesh, maize has emerged as one of the major cereal crops in 3.52 lakh ha with an annual production of 22.1 lakh tonnes in 2013-2014. Kurnool district with an area of 0.52 lakh ha enjoy a production of 3.1 lakh tonnes in

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Table 1. Area and production of maize in different states in India (2013-14)

S. No.	States	Area (m. ha)	Production (m. tonnes)
1	Karnataka	1.38	3.98
2	Maharashtra	1.21	3.08
3	Andhra Pradesh	1.06	4.97
4	Madhya Pradesh	1.00	1.51
5	Rajasthan	0.93	1.50
6	Bihar	0.75	2.02
7	Uttar Pradesh	0.74	1.24
8	Gujarat	0.46	0.69
9	Tamil Nadu	0.30	1.64
10	Jammu and Kashmir	0.30	0.53
11	Himachal Pradesh	0.29	0.68
12	Jharkhand	0.26	0.52
13	West Bengal	0.13	0.52
14	Punjab	0.13	0.51
15	Others	0.48	0.97

Source: Ministry of Agriculture, Govt. of India, 2013-14.

Table 2. Efficiency measures and descriptive statistics across farms according to scale of operations

Scale of operations	Efficient farms ($\theta = 0.90$)		Efficiency measures			
	No.	%	Mean	Standard deviation	Maximum	Minimum
Marginal farmers						
Technical efficiency (Constant returns)	18	29.51	0.6572	0.2916	1	0.0775
Technical efficiency (Variable returns)	27	44.27	0.8202	0.1751	1	0.4468
Scale efficiency	33	54.09	0.7917	0.2895	1	0.106
Small farmers						
Technical efficiency (Constant returns)	10	29.41	0.7202	0.2293	1	0.2941
Technical efficiency (Variable returns)	16	47.06	0.8594	0.1490	1	0.5043
Scale efficiency	18	52.94	0.8360	0.1997	1	0.2942
Other farmers						
Technical efficiency (Constant returns)	11	44.00	0.8290	0.1763	1	0.3962
Technical efficiency (Variable returns)	18	72.00	0.9471	0.076	1	0.776
Scale efficiency	16	64.00	0.8761	0.1724	1	0.3962
Pooled farmers						
Technical efficiency (Constant returns)	22	18.33	0.6241	0.2601	1	0.0595
Technical efficiency (Variable returns)	42	35.00	0.7537	0.2176	1	0.1923
Scale efficiency	65	54.17	0.8293	0.2316	1	0.0816

Table 3. Category-wise distribution of farmers in Kurnool district according to types of returns to scale among different scale of operations

Types of returns to scale	Marginal farmers	Small farmers	Other farmers	Total farmers
Increasing	41 (67.21)	21 (61.77)	11 (44.00)	75 (62.50)
Constant	13 (21.31)	7 (20.59)	9 (36.00)	15 (12.50)
Decreasing	7 (11.48)	6 (17.64)	5 (20.00)	30 (25.00)
Total	61 (100)	34 (100)	25 (100)	120 (100)

Figures in parentheses indicate percentages to the respective column totals

Table 4. Determinants of CRS (Resource Use Efficiency) of maize farms in Kurnool district

Variables	Marginal farms	Small farms	Other farms	Pooled farms
Intercept	0.4176	0.3107	0.1927	0.2163
(X ₁) Irrigation cost	0.0427**	0.0407**	0.0316**	0.0372**
(X ₂) Fertilizer cost	0.0763**	0.0614**	0.0421**	0.0626**
(X ₃) Pesticide cost	0.0871 ^{NS}	0.0916 ^{NS}	0.0893*	0.0816*
(X ₄) Human labour cost	0.0672*	0.0416*	0.0361**	0.0313*
Adjusted R ²	0.73**	0.64**	0.78**	0.81**

*: Significant at 5% level; **: Significant at 1% level; ^{NS}: Non-Significant

the same year thereby, accounting for 14.77 and 14.02 percents share respectively at Andhra Pradesh level. Kurnool district in Andhra Pradesh had got good reputation as an important maize grower of Andhra Pradesh since long time. In view of the potentiality of maize crop in Kurnool district, its economic analysis has assumed greater significance. However, not much of literature was available pertaining to the technical efficiency of resource usage in maize production in Rayalaseema region of Andhra Pradesh in general and in Kurnool district in particular. From this background, it emanates the need for an in depth microscopic study on analyzing the resource use efficiency in maize cultivation by using DEA approach in Kurnool district. The results of the study would be useful to maize farmers of Kurnool district in particular and of Andhra Pradesh in general in identifying the management plans for enhancing resource use efficiency in cultivating maize. They further indicate, whether there is any scope for reorganisation and reallocation of resources that would contribute to the

realisation of constant returns to scale among the farmers. Keeping this goal in view, the following specific objectives were formulated for this in-depth investigation.

1. To analyse the resource use efficiency and its determinants in the production of maize.
2. To analyse the determinants of technical efficiency in the production of maize.

MATERIALS AND METHODS

Kurnool district in Andhra Pradesh was purposively selected for the study, as the district ranks first in the cultivation of maize in Rayalaseema region of Andhra Pradesh state after its bifurcation during 2013-14. Top two mandals in terms of area under maize cultivation in Kurnool district viz., Nandikotkur and Pamulapaadu were selected. From the list of villages arranged in descending order of acreage under maize, top two villages from each mandal were selected. For the selection of farmers, a list

of farmers from the selected villages was obtained from the respective Gram Panchayat Offices. To analyze the resource use efficiency, the farmers were conveniently categorized according to their land holding size i.e., Marginal (<1 ha), Small (1-2 ha) and Other farmers (>2 ha). From these three different categories, a total of 120 farmers were selected at random based on probability proportional to size. So, the sampling frame consists of one district, two mandals, four villages and 120 farmers which forms the basis to elicit the requisite data. A well structured pre-tested schedule was employed to collect the requisite information from the sample farmers. The study was conducted in the year 2013-14.

DEA Model

The DEA method is a frontier method that does not require specification of a functional or distributional form, and can accommodate scale issues. This approach was first used by Farrell (1957) as a piecewise linear convex hull approach to frontier estimation and later by Boles (1966) and Afriat (1972). This approach did not receive wide attention till the publication of the paper by Charnes *et al.* (1978), which coined the term Data Envelopment Analysis. A large number of papers have extended and applied the DEA technology in the western world. Very few studies have used this approach in India, especially in agriculture and no studies were conducted so far for analyzing the resource use efficiency that too in Andhra Pradesh. DEA method has the disadvantage that it does not explicitly accommodate the effects of data noise. In the present case, the DEA method was preferred because, data noise was less of an issue as most of the variables in analyzing resource use efficiency were included and because of its ability to readily produce rich information on technical efficiency, and scale efficiency.

Several DEA models have been presented in the literature. The basic DEA model evaluates efficiency based on the productivity ratio which is the ratio of outputs to inputs. This study applied Charnes, Cooper and Rhode’s (CCR) (1978) model and Banker, Charnes and Cooper (BCC) (1984) model. The production frontier has constant returns to scale in CCR model. The basic CCR model formulation (dual problem/ envelopment form) is given by:

The basic CCR model formulation (dual problem/ envelopment form)

$$\text{Min } \theta - \alpha \left(\sum_{j=1}^m s_j^- + \sum_{r=1}^s s_r^+ \right)$$

Subject to:

$$\sum_{j=1}^n \lambda_j x_{ij} + s^- = \theta x_{i0} \quad (i=1, \dots, m)$$

$$\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0} \quad (r=1, \dots, s)$$

$$\lambda_j \geq 0 \quad (j=1, \dots, n)$$

Source: Zhu (2003, p. 13)

where, θ denotes the efficiency of Decision Making Unit (DMU_j), while y_{rj} is the amount of r^{th} output produced by DMU_j using x_{ij} amount of i^{th} input. Both y_{rj} and x_{ij} are exogenous variables and θ_j represents the benchmarks for a specific DMU under evaluation (Zhu 2003). Slack variables are represented by s_i^- and s_r^+ . According to Cooper, Seiford and Tone (2004) the constraints of this model are:

- i. The combination of the input of firm j is less than or equal to the linear combination of inputs for the firm on the frontier;
- ii. The output of firm j is less than or equal to the linear combination of outputs for the firm on the frontier; and
- iii. The main decision variable θ_j lies between one and zero.

Further, the model assumes that, all firms are operating at an optimal scale. However, imperfect competition and constraints to finance may cause some firms to operate at some level different to the optimal scale (Coelli, Rao and Battese 1998). Hence, the Banker, Charnes and Cooper (1984) BCC model is developed with a production frontier that has variable returns to scale. The BCC model forms a convex combination of DMUs (Coelli, Rao and Battese 1998). Then the constant returns to scale linear programming problem can be modified to one with variable returns to scale by adding the convexity constraint $\sum \lambda_j = 1$. The model given below illustrates the basic BCC formulation (dual problem/envelopment form):

The basic BCC model formulation (dual problem/ envelopment form)

$$\text{Min } \theta - \alpha \left(\sum_{j=1}^m s_j^- + \sum_{r=1}^s s_r^+ \right)$$

Subject to:

$$\sum_{j=1}^n \lambda_j x_{ij} + s^- = \theta x_{i0} \quad (i=1, \dots, m)$$

$$\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0} \quad (r=1, \dots, s)$$

$$\lambda_j \geq 0 \quad (j=1, \dots, n)$$

$$\sum_{j=1}^n \lambda_j = 1$$

Source: Zhu (2003, p. 13)

This approach forms a convex hull of intersecting planes (Coelli, Rao and Battese 1998). These planes envelop the data points more tightly than the Constant Returns to Scale (CRS) conical hull. As a result, the Variable Returns to Scale (VRS) approach provides technical efficiency (TE) scores that are greater than or equal to scores obtained from the CRS approach (Coelli, Rao and Battese 1998). Moreover, VRS specifications will permit the calculation of TE decomposed into two components: Scale Efficiency (SE) and Pure Technical Efficiency (PTE). This study first uses the CCR model to assess TE then applies the BCC model to identify PTE and SE in each DMU. The relationship of these concepts is given below:

Relationship between TE, PTE and SE: This is given by

$$TE_{CRS} = PTE_{VRS} * SE$$

where,

TE_{CRS} = Technical efficiency of constant return to scale

PTE_{VRS} = Technical efficiency of variable return to scale

SE = Scale efficiency

Source: Coelli, *et al.*, (1998).

The above relationship, which is unique, depicts the sources of inefficiency, i.e., whether it is caused by inefficient operation (PTE) or by disadvantageous conditions displayed by the scale efficiency (SE) or by both. If the scale efficiency is less than 1, the DMU will be operating either at Decreasing Return to Scale (DRS) if a proportional increase of all input levels produces a less-than-proportional increase in output levels or Increasing Return to Scale (IRS) at the converse case. This implies that resources may be transferred from DMUs

operating at DRS to those operating at IRS to increase average productivity at both sets of DMUs (Boussofiane *et al.*, 1992).

Data and Variables considered in the Study

DEA assumes that, the inputs and outputs have been correctly identified. Usually as the number of inputs and outputs increase, more DMUs tend to get an efficiency rating of 1 as they become too specialized to be evaluated with respect to other units. On the other hand, if there are too few inputs and outputs, more DMUs tend to be comparable. In any study, it is important to focus on correctly specifying inputs and outputs. For every inefficient DMU, DEA identifies a set of corresponding efficient DMU that can be utilized as benchmarks for improvement of performance and productivity. DEA is developed based on two scales of assumptions viz., CRS model and VRS model. CRS means that the farmers are able to linearly scale the inputs and outputs without increasing or decreasing efficiency. This is a significant assumption. The assumption of CRS may be valid over limited ranges, but its use must be justified. As an aside, CRS tends to lower the efficiency scores while VRS tends to raise efficiency scores.

For enabling the study of evaluation of resource use efficiency of maize farmers, the researcher observed the resources or inputs and productivity indicators or outputs as follows:

Inputs: X_1 – Irrigation cost (Rs), X_2 - Fertilizers cost (Rs.), X_3 – Pesticides cost (Rs.), (X_4) – Human labour cost (Rs.)

Outputs: Y_1 – Assets created on the farm (Rs.), Y_2 – Gross returns from maize (Rs.)

The present study involves the application DEA to assess the resource use efficiency of 120 maize cultivating farmers in the year 2013-14. This model is executed using input-orientation with radial distances to the efficient frontier. The DEA was solved using the MAXDEA version 5.2 taking an input orientation to obtain the efficiency level

Determinants of Technical Efficiency

Ray (1991) and Worthington and Dollery (1999), used traditional DEA in the first stage to estimate the technical efficiency and in the second stage estimated the determinants of technical efficiency from the factors

contributing to this technical efficiency by using econometric procedure. In the present study, the technical efficiency values obtained from the DEA model considering the CRS input-oriented model were used for examining the relationship between the technical efficiency and factors influencing it. The technical efficiency score from CRS model was chosen as the dependent variable for its high accuracy in discriminating efficiency as compared to variable returns to scale (Goncalves *et al.*, 2008). The above inputs are considered as explanatory variables. The traditional method of regression was used for this purpose and OLS analysis was carried out to estimate the regression equation. The regression model specified for the present study is given in the following equation:

$$Y = a X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} \mu$$

where, Y = Technical efficiency scores (CRS), X₁ – Irrigation cost (Rs), X₂ - Fertilizers cost (Rs.), X₃ – Pesticides cost (Rs.) and X₄ – Human labour cost (Rs.), ‘a’ and ‘bi’ are the constant and the coefficients respectively, which were estimated through the OLS analysis after appropriate log conversion.

RESULTS AND DISCUSSION

To compute resource use efficiency in maize production, DEA approach was employed in the first stage to estimate the technical efficiency and in the second stage estimated the determinants of technical efficiency from the factors contributing to this technical efficiency by using econometric procedure.

i. Technical efficiency in maize

To obtain efficiency levels of each of the farms as decided by the physical inputs (quantities), DEA models, which are input-oriented, were used at different production scales under the assumption of CRS. After introducing convexity in the CRS model, the VRS were estimated. By using the efficiency levels of these CRS and VRS models, the scale efficiency for each farm was obtained. The results on efficiency measures (with constant and variable returns) and the descriptive statistics for maize producing farms in the Kurnool district are given in Table 2.

Marginal farms

It was observed from Table 2 that, only 29.51 per cent of farms under assumption of CRS performed with efficiency level equal to 0.90 or greater, i.e. 18 of the

total 61 farms. The average efficiency score was 0.6572. Based on this, it could be inferred that remaining 43 farms, which did not operate at the maximum efficiency level, could reduce the input level by 34.28 per cent and maintain the same level of maize production as achieved by 29.51 per cent of the farmers. When the assumption of constant scale was relaxed and the model with VRS was calculated, the impact of production scale on technical efficiency level was visible. In marginal farms, the number of efficient farms was 44.27 per cent and the average technical efficiency score increased to 0.8202. These better results from the model with variable returns were mainly due to the inclusion of scale efficiency, which the previous model did not take into consideration. As regards to the scale efficiency, about 54.09 per cent of maize farms (33 out of 61 farms) under marginal farms category, either performed at the optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

Small farms

Under the assumption of CRS, about 29.41 per cent of the farmers in this category were found efficient with values equal to or more than 0.90, i.e., (10 out of 34 farms). The average technical efficiency score in this category was 0.7202. Based on this, it could be inferred that remaining 24 farms, which did not operate at the maximum efficiency level, could reduce the input level by 27.98 per cent and maintain the same level of maize production as achieved by 29.41 per cent of the farmers. In the case of variable returns, the average technical efficiency score was 0.8594 and nearly 47.06 per cent of the farms had the score equal to or more than 0.90. As regards to the scale efficiency, nearly 53 per cent of the small farms (18 out of 34 farms) either performed at the optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

Other farms

It was observed that, 44 per cent of farms under the assumption of CRS performed with efficiency level equal to 0.90 or greater, i.e., 11 out of total 25 farms. The average efficiency score was 0.8290. This indicates that remaining 14 farms, which did not operate at maximum efficiency level, could reduce the input level by 17.10 per cent and maintain the same level of maize production as achieved by 44 per cent of the farmers. Nearly 72 per cent of the other farms are being operated at VRS with an average

technical efficiency score of 0.9471. As regards to the scale efficiency, 64 per cent of the farmers (16 out of 25 farmers) under other farms either performed at optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

From the above analysis it is clear that, the number of farms operating at CRS are more in number in other farms (44%) followed by marginal (29.51%) and small farms (29.41%). Similarly, regarding the number of farmers operating at VRS, the other farms are again more in number with 72 per cent followed by small (47.06%) and marginal farms (44.27%). With reference to scale efficiency, again other farms dominate the scenario with 64 per cent followed by marginal (54.09%) and small farms (52.94%). At pooled level, 18.33 per cent of the farms are being operated at CRS with an average technical efficiency score of 0.6241 i.e., 22 out of 120 farms. This indicates that, remaining 98 farmers, who did not operate at the maximum efficiency level, could reduce the input level by 37.59 per cent and maintain the same level of efficiency as achieved by 18.33 per cent of the farmers. Thirty five per cent of the farmers at pooled level are being operated at VRS with an average technical efficiency score of 0.7537. As regards to scale efficiency, 54.17 per cent of the farmers (65 out of 120 farmers) at pooled level, either performed at the optimum scale or were close to the optimum scale (farms having scale efficiency values equal to or more than 0.90).

ii. Regions of Operations in the Production Frontier

In addition to knowing about the number of efficient farms, extent of inefficiency and optimum scale of operation, it is also important to understand the distribution of farms in the three regions of production frontier, i.e. how many farms are under increasing, decreasing or constant returns. These were estimated using the equations given under methodology and the results have been presented in Table 3.

Around 67 per cent of the farms in the marginal farms category were found operating in the region of increasing returns or the sub-optimal region. The production scale of these farms could be increased by decreasing the costs, since they were performing below the optimum production scale. Only 11.48 per cent of maize farms in the marginal farms category were found in the decreasing returns region and these farmers could increase their technical efficiency by reducing their input usage consequently their production levels. This region is also called as supra-optimal i.e., the farms were performing above the

optimum scale of production. In the constant region of frontier i.e., optimum scale of production, 21.31 per cent of the marginal farms were found operating. Regarding small and other farms 17.64 and 20.00 per cents respectively are operating at DRS and 61.77 per cent and 44.00 per cents respectively are operating at IRS respectively. This signifies that, for the farmers operating at IRS are to be provided with more resources and the same should be decreased towards the farmers operating at DRS. Compared to other farms category, there are less number of farmers operating at CRS both in small farms category (20.59%) and marginal farms category (21.31%). This indicates that, there is more efficient utilization of resources by other farms compared to small and marginal farms.

On the whole, majority of the farmers (62.50%) are operating at IRS and only 25 per cent of the farmers are operating at DRS. This signifies that, more resources should be provided to these farms operating at IRS and the same should be decreased towards the farms operating at DRS. 12.5 per cent of the farms are operating at CRS indicating efficient utilization of resources.

iii. Determinants of input-use (CRS technical) efficiency of maize farms:

Log linear regression model was used to analyze the major determinants of input use efficiency of maize farms. The input variables considered under DEA model were again considered as influential factors for the CRS obtained for the three categories of farmers. The analytical findings (Table 4) revealed that, across all the categories of farmers and at pooled level, the models are statistically significant, as indicated by higher and significant Adjusted R^2 values. The two variables irrigation cost (X1) and fertilizer cost (X2) (both positively influencing at 1% level) are the major determinants of Resource Use Efficiency (CRS) of all the selected farmers categories and at pooled level. Among these two, fertilizer cost (X2) is the major influential factor for CRS compared to irrigation cost (X1) across all the categories of maize farmers and at pooled level. Human labour cost (X4) also found to be significantly influencing the CRS of all categories of maize farmers and at pooled level, but remained significant at 5% level except other farmers (at 1% level). It is heartening that, marginal and small farmers are resorting to low dosages of pesticide application in view of their higher prices in the market and hence, this variable is not exerting any significant influence on the CRS of these farmers. However, other farmers are resorting

for pesticide application to control pests and diseases on the crop and this significantly influenced (5% level) the CRS. Even at pooled level, this variable (X3) was found exerting significant (5% level) influence on the CRS.

Thus, irrigation cost (X1) and fertilizer cost (X2) are the major determinants of maize farms across all the farmer categories and even at pooled level. In view of their positive influence on the CRS, it is essential to strengthen modern irrigation infrastructure like drip irrigation and offer more fertilizer subsidies to the farmer to enhance the crop production on cost-effective basis.

SUMMARY AND CONCLUSIONS

The above analysis regarding resource use efficiency of maize farmers revealed that, it is evident that, 12.5 per cent of farmers are operating at CRS indicating efficient utilization of resources. Majority of the farmers (62.50%) *i.e.*, 75 out of 120 are operating at IRS and only 25 per cent of the farmers (30 out of 120 farmers) are operating at DRS indicating that, more resources should be provided to the farms operating at IRS and the same should be decreased towards the farms operating at DRS. The following policy implications must be borne in mind to improve the resource use efficiency of maize farmers in Kurnool district:

- It was found that, the sample farmers are spending huge amount on applying chemical and fertilizers. So, it is also advocated to adopt INM, so as to ensure both cost effective and quality production of maize. The on-farm demonstrations need to be conducted to educate the farmers on these technologies.
- Since, majority of the farmers (62.50%) are operating at IRS and only 25 per cent of the farmers are operating at DRS, more resources should be provided to the farmers operating at IRS and the same should be decreased for the farmers operating at DRS, so as to make the former farms to be resource efficient.

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NUTRIENT STATUS OF GROUNDNUT (*Arachis hypogaea* L.) GROWING SOILS IN EASTERN MANDALS OF CHITTOOR DISTRICT, ANDHRA PRADESH

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ABSTRACT

A survey was undertaken to study the nutrients status of groundnut growing soils in eastern mandals of Chittoor district of Andhra Pradesh. The texture of the soils varied from sandy loam to sandy clay loam, neutral to slightly alkaline in reaction, non-saline, low to medium in organic carbon and available nitrogen and medium to high in available P and K. However, available Ca, Mg, S, Fe, Mn, Zn and Cu were found to be above critical limits in all the soils. Simple correlation studies revealed that available N, S, Fe, Mn, Cu and Zn were positively and significantly correlated with clay content and organic carbon. However, available P, K, Ca and Mg were negatively and significantly correlated with clay content.

KEYWORDS: Groundnut soils, Macronutrients, Micronutrients

INTRODUCTION

Mineral nutrition has been recognized as an important constraint in crop production. Systematic and periodic identification of current nutrient deficiencies and sufficiencies is a prerequisite for sustaining the productivity and fertility of soils. Groundnut is a major oilseed cum cash crop in India as well as in particular in Andhra Pradesh. It is cultivated in an area of about 13.86 lakh ha with an annual production of 12.34 lakh tones (www.nmoop.gov.in Status paper on oilseeds, 2014) in Andhra Pradesh. Several groundnut growing areas of our country are unable to supply the available nutrients at the rate at which the groundnut the crop requires for its maximum growth and yield. Hence, the present survey was taken up to study the nutrient status in groundnut growing soils of eastern mandals in Chittoor district of Andhra Pradesh.

MATERIALS AND METHODS

The study area includes major groundnut grown eastern mandals in Chittoor district of Andhra Pradesh viz., Vadamalapet, Narayanavanam, Nagari, Vijayapuram, Nindra, Nagalapuram, Kalahasti, Thottembedu, Karvetinagaram, G.D Nellore and Yerpedu which lies in between 13° 30' and 14° 00' N latitudes and 78° 05' and 78° 50' E longitudes.

Soil samples were collected from 60 groundnut growing fields located these in Eastern mandals of Chittoor

district. From each field, three soil samples were collected at a depth of 0-30 cm and the samples in each field were thoroughly mixed so as to obtain one composite sample. All the 60 soil samples were analysed for pH, EC, organic carbon and available K by adopting standard procedures (Jackson, 1973). Available N was determined by alkaline permanganate method (Subbiah and Asija, 1956). The available P was extracted with 0.5M NaHCO₃ extractant (Olsen *et al.*, 1954) and determined by using ascorbic acid as reducing agent (Watanabe and Olsen, 1965). Available Ca and Mg were determined by versenate method (Chopra and Kanwar, 1991) whereas available S was determined by turbid metrically using 0.15% CaCl₂ extractant (Cottenie *et al.*, 1979) and available (DTPA extractable) Fe, Mn, Zn and Cu were determined as per Lindsay and Norvell (1978).

Soil samples were rated as low, medium and high categories as per the limit suggested by Muhr *et al.* (1965) for organic carbon, available N, P and K. Available Ca and Mg were classified based on the critical limits proposed by Tandon (1989) while available S was rated as per the critical limits established by Tandon (1991). In respect of available Fe, Mn and Cu, the ratings given by Lindsay and Norvell (1978) were followed. Nutrient Indices (N.I) for available N, P and K were worked out as per the formula given by Parkar *et al.* (1951). Simple correlation analysis was also carried out between soil physical and physico-chemical characteristics and available soil nutrients as per the procedures described by Gomez and Gomez (1984).

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RESULTS AND DISCUSSION

The texture of the soils varied from sandyloam to sandyclayloam (Table 1). This variation in soil texture might be due to the variation in topographic position, nature of parent material, *in situ* weathering of clay and age of soils. pH of the groundnut growing soils varied from 6.43 to 8.70. The variation in pH might be attributed to the variation in nature of parent material and degree of weathering. Similar findings were reported by Leelavathi *et al.* (2009) in soils of Chittoor district. The EC values varied between 0.04 and 0.86 dSm⁻¹ indicating non-saline nature of these soils. The organic carbon content in these soils ranged from 0.13 to 0.50 per cent. The low organic carbon content in these soils might be due to rapid oxidation of organic matter as the climate of the area is tropical.

Available N, P, K, Ca, Mg and S

The groundnut growing soils were low in available N with overall nutrient index value 1.00 while available P and K were low to high with overall nutrient index values varying from 1.25 to 2.40 and 1.00 to 2.20, respectively (Table 2). The low available nitrogen status of these soils might be attributed to low organic carbon

content. Further, the semi-arid conditions of the area might have favoured the rapid oxidation and less accumulation of organic matter releasing more NO₃-N which could have been lost by leaching (Finck and Venkateswarlu, 1982). Medium to high availability of P in these soils was attributed to the continuous use of phosphatic fertilizers like single super phosphate by the farmers. The higher values of K could be ascribed to more weathering of potassium bearing minerals, alternate wetting and drying cycles and release of K from decomposing organic matter added to the surface.

Available Ca (1.75 to 16.00 cmol (P⁺) kg⁻¹ soil), Mg (0.25 to 14.00 cmol (P⁺) kg⁻¹ soil) and S 10.25 to 48.75 mg kg⁻¹ soil in these groundnut growing soils were found to be above their respective critical limits (Table 3). Similar findings were reported by Thangasamy (2002).

Available Fe, Mn, Cu and Zn

Available (DTPA extractable) Fe, Mn, Zn and Cu in groundnut growing soils ranged from 7.31 to 34.48, 2.10 to 23.80, 1.02 to 2.76 and 0.59 to 2.62 mg kg⁻¹ soil, respectively (Table 3). All the available micronutrients are above their respective critical limits. These findings were in accordance with findings of Bhupal Raj *et al.* (2006)

Table 1. Soil test summary - soil texture, pH, EC and organic carbon (mean values) in groundnut grown soils of Chittoor district

Sl. No.	Mandal	Number of samples	Soil texture	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)
1.	Vadamalapet	4	s-sl	7.37	0.13	0.27
2.	Narayanavanam	5	s-sl	7.20	0.28	0.13
3.	Nagari	6	ls-c	7.53	0.45	0.50
4.	Vijayapuram	5	s-sl	7.01	0.18	0.14
5.	Nindra	5	sl-c	7.71	0.26	0.43
6.	Nagalapuram	10	sl-scl	7.38	0.25	0.35
7.	Kalahasti	5	sl-scl	8.08	0.18	0.21
8.	Thottembedu	5	sl-scl	7.68	0.28	0.18
9.	Karvetinagaram	6	ls-scl	7.44	0.20	0.17
10.	G.D Nellore	5	ls-scl	7.38	0.18	0.26
11.	Yerpedu	4	s-c	7.89	0.27	0.37
	Total	60	s-c	7.52	0.24	0.24

ls: loamy sand; sl: sandy loam; scl: sandy clay loam; s: sand; c: clay

Table 2. Soil test summary - available N, P and K in groundnut grown soils of Chittoor district

Sl. No.	Mandal	Number of samples	Available N			Available P			Available K		
			Mean (kg ha ⁻¹)	Nutrient index	Fertility status	Mean (kg ha ⁻¹)	Nutrient Index	Fertility status	Mean (kg ha ⁻¹)	Nutrient Index	Fertility status
1.	Vadamalapet	4	162.8	1.00	L	10.1	1.25	L	85.7	1.00	L
2.	Narayanavanam	5	135.3	1.00	L	15.7	1.80	M	104.9	1.20	L
3.	Nagari	6	143.1	1.00	L	15.3	1.83	M	132.4	1.33	L
4.	Vijayapuram	5	145.3	1.00	L	16.7	2.00	M	94.3	1.00	L
5.	Nindra	5	120.4	1.00	L	20.2	2.20	M	222.2	2.20	M
6.	Nagalapuram	10	130.4	1.00	L	17.0	1.90	M	122.4	1.30	L
7.	Kalahasti	5	135.5	1.00	L	18.0	2.00	M	97.8	1.00	L
8.	Thottembedu	5	160.4	1.00	L	10.4	1.40	L	86.2	1.00	L
9.	Karvetinagaram	6	160.7	1.00	L	12.4	1.50	L	85.5	1.00	L
10.	G.D Nellore	5	120.4	1.00	L	21.2	2.40	H	206.4	2.00	M
11.	Yerpedu	4	144.1	1.00	L	16.8	2.00	M	95.6	1.00	L

L: Low; M: Medium; H: High

Table 3. Soil test summary - available Ca, Mg, S, Fe, Mn, Zn and B in groundnut grown soils of Chittoor district

Sl. No.	Mandal	Number of samples	Available secondary nutrients				Available micronutrients (mg kg ⁻¹)			
			Ca (cmol (p+) kg ⁻¹)	Mg (cmol (p+) kg ⁻¹)	S (mg kg ⁻¹)	Fe	Mn	Cu	Zn	
1.	Vadamalapet	4	4.06	1.97	37.08	27.66	16.05	2.19	1.99	
2.	Narayanavanam	5	6.28	4.24	28.00	21.82	9.26	1.56	1.49	
3.	Nagari	6	6.44	4.11	29.12	22.61	10.87	1.72	1.59	
4.	Vijayapuram	5	5.72	3.72	28.75	22.85	9.20	1.56	1.53	
5.	Nindra	5	10.32	8.39	19.30	15.69	6.05	1.34	1.09	
6.	Nagalapuram	10	6.78	4.70	25.72	21.14	8.09	1.48	1.40	
7.	Kalahasti	5	6.35	3.96	27.50	22.53	8.15	1.40	1.38	
8.	Thottembedu	5	4.01	2.04	36.50	27.05	15.08	2.14	1.95	
9.	Karvetinagaram	6	4.35	2.42	34.79	25.54	13.30	1.98	1.89	
10.	G.D Nellore	5	9.22	7.27	19.05	17.75	5.54	1.28	1.10	
11.	Yerpedu	4	5.78	3.87	28.75	22.61	9.04	1.55	1.52	

Table 4. Correlation coefficients (r) between soil characteristics and available soil nutrients

	N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn
Clay	0.203**	-0.136*	-0.159**	-0.207**	-0.194**	0.208**	0.203**	0.172**	0.167	0.179*
PH	-0.961	0.962	0.671**	0.899*	0.879**	-0.952	-0.921*	-0.965*	-0.971*	-0.973
EC	-0.733*	0.714	0.910**	0.905**	0.927**	-0.782	-0.862	-0.674	-0.622	-0.749
OC	0.875**	-0.875	-0.823**	-0.794**	0.894**	0.894**	0.880**	0.918**	0.896**	0.907**

*: Significant at 1% level; **: Significant at 5% level

Nutrient status of groundnut growing soils

who stated that micronutrients in soils of Andhra Pradesh were found to be above their respective critical limits.

CORRELATION STUDIES

pH, EC, OC and Clay vs Available macronutrients

Simple correlations were worked out between various soil characteristics and available macronutrients (Table 4). Available N and S were positively and significantly correlated with clay content and organic carbon while available P, K and Ca were negatively and significantly correlated with clay content of the soil. The positive association of available N and S with clay content and organic carbon might be due to the fact that the later were the primary reservoirs of the former. However, the negative relation between available P and clay content might be due to the fixation of the applied P (Singh *et al.*, 2001).

Available P, K, Ca and Mg were positively and significantly correlated with soil pH and EC of the soil. Available potassium was positively and significantly correlated with pH of the soils. In these soils organic matter and clay fraction might be the primary reservoirs of exchangeable potassium. Kalbande and Swamynatha (1976) reported similar relationship between exchangeable potassium and pH in black soils of Tungabhadra catchment.

pH, EC, OC and clay Vs Available micro nutrients

Available Fe, Mn, Zn and Cu were positively and significantly correlated with clay content and organic carbon. The positive relationship between organic carbon and available micronutrients is ascribed to its affinity to influence the solubility and availability of micronutrients by chelation effect which might have protected the later from oxidation and precipitation which consequently increased their availability (Prasad and Sakal, 1991).

Available micronutrients were negatively and significantly correlated with soil pH, which might be due to the fact that these micronutrients are oxidized to their respective higher oxides which are unavailable to plants. Similar findings were reported by Munaswamy *et al.* (1989)

CONCLUSION

The ground nut grown soils were neutral to slightly alkaline in reaction, non-saline, low to medium in available N and medium to high in available P and K. Hence, integrated uses of organics with inorganic

fertilizers coupled with inoculation of efficient strain of *Rhizobium* not only increases the available N but also sustains the yield of groundnut crop.

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RELATIONSHIP BETWEEN PERSONAL CHARACTERISTICS AND ASPIRATIONS OF THE POST GRADUATE STUDENTS OF POST GRADUATE INSTITUTE, RAHURI AND COLLEGE OF AGRICULTURE, PUNE

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ABSTRACT

This research study was undertaken at College of Agriculture, Pune and Post Graduate Institute, of MPKV, Rahuri of Maharashtra State during the year 2011-12. Expost-facto research design was used for the study. The observations keenly revealed that the characteristics namely academic performance of post graduate students in H.S.C. and fathers' annual income have positive and significant relationship with aspirations of post graduate students at 5.00 per cent level of probability whereas the relationship between size of landholding and aspirations of post graduate students is positive and significant at 1.00 percent level of probability. However the relationship between other characteristics namely academic performance of post graduate students in Under graduation, family education status, fathers' occupation is non significant, whereas there is negative and non significant relationship between post graduate students mothers' occupation and annual income.

KEYWORDS: Personal characteristics, Aspirations, Post-graduate students, Relationship

INTRODUCTION

Among human resources of any nation, the vital chunk happens to be its youth. India has a power of youth. Youth stands for aspirations. Youth have been playing quite a significant role in almost every country of the world as they possess the zeal and vigour necessary to create opportunities for national development (Bhanu, 2006). Youth stand for aspirations. In the present study the post graduate students do have some aspirations. They have the desire to know, explore and experiment. They have the ability to learn and enrich their knowledge. These aspirations may be influenced by some academic, personal, socio-psychological variables. There are various factors which may determine level of aspirations and educational achievements. Poor academic performance leads to lack of fruitful aspirations and subsequently results in loss of confidence of the incumbent. The personal characteristics and the family background of the students may greatly influence their aspirations and educational achievements. Hence the research paper presents the results about the relationship between the personal characteristics and aspirations of the post graduate students.

MATERIAL AND METHODS

The present study was conducted in College of Agriculture, Pune and Post Graduate Institute, Rahuri which are under Mahatma Phule Krishi Vidyapeeth of Maharashtra state during the academic year 2011-12. Expost facto research design was followed for the present study. The total sample constituted 93 post graduate students of Post Graduate Institute, Rahuri and 27 post graduate students of College of Agriculture, Pune with a total of 120 students by following Proportionate Stratified Random Sampling. The data were collected with the help of structured interview schedule. The statistical tool used in this study include correlation coefficient (r).

RESULTS AND DISCUSSION

The study of relationship between personal characteristics of respondents and their aspirations is one of the important objectives of the actual study on Aspirations of Post graduate students. Hence findings of that particular objective are presented in this research paper.

1. Academic Performance and aspirations

a) The academic performance of the post graduate students with respect to percentage of marks scored in

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Table 1. Correlation between personal characteristics and aspirations of the Post graduate students

Sl. No.	Characteristics	Correlation coefficient (r)
1.	Academic performance	
	a) Percentage marks in XII	0.23*
	b) CGPA in Under-Graduation	0.14 ^{NS}
2.	Type of Family	0.07 ^{NS}
3.	Family Education status	
	a) Fathers' Education	0.11 ^{NS}
	b) Mothers' Education	0.05 ^{NS}
4.	Size of Land Holding	0.25**
5.	Parents' Occupation	
	a) Fathers' Occupation	0.07 ^{NS}
	b) Mothers' Occupation	-0.13 ^{NS}
6.	Family Annual Income	
	a) Fathers' Annual Income	0.23*
	b) Mothers' Annual Income	-0.14 ^{NS}

D.F: 118; *: Significant at 0.005 probability level; **: Significant at 0.001 probability level; ^{NS}: Non-Significant

XII standard had a profound influence on the aspirations of post graduate students. The 'r' value of 0.23 from the table I supported the prior assumption showing a positive and significant relationship at 5.00 per cent level of significance. It clearly indicated that the post graduate students who secured higher percentage of marks in XII standard had chosen agriculture education in the face of alternatives. This may be due to the realization of fact that any degree in agriculture gives secured government job and also because of the proximity of agriculture education to research and competitive exams. More *et al.* (2008) found that there was a significant relationship between academic performance in XII standard and aspirations of agricultural students.

b) The 'r' value 0.14 from table I revealed that, there is no statistically significant relationship between the Cumulative Grade Point Average (C.G.P.A) in under-graduation of the post graduate students and their aspirations. This means, aspirations of the post graduate students were not influenced by their Cumulative Grade Point Average (C.G.P.A) in under-graduation.

2. Type of family and aspirations

The correlation between type of family and the aspirations of the post graduate students was found to be non-significant. It suggested that there is no impact of

type of family on the aspirations of the post graduate students. The 'r' value of 0.07 from table 13 supported the above statement. It can be inferred that whatever may be the type of family i.e. either nuclear or joint it does not show any impact on aspirations of the post graduate students. Jadhav (2008) reported that there was a non-significant relationship between type of family and aspirations.

3. Family Education status and aspirations

The relationship between Family Education status and aspirations of the post graduate students was found to be non-significant. It means Family Education status of the post graduate students did not influence their aspirations. The 'r' values from the table 13 supported the above statement. The aspiration and level of the aspirations are fields of the personal phenomena. Due to this, though the family's characteristics are likely to influence the aspiration level of an individual, the influence might not be significant. The findings were in far with the study conducted by Saritha (2000).

4. Size of Land holding and aspirations

Parents with large size of land holding have high socio-economic status, greater social participation, and high risk taking ability, have greater exposure and more

opportunities for higher education. It was therefore, assumed that post graduate students with large sized land holding might be having higher aspirations. The 'r' value of 0.25 from table 13 supported this assumption showing that the correlation between size of land holding and the aspirations of the post graduate students was highly significant at 1.00 percent level of probability. Deshmukh (2005) reported a significant relationship between size of land holdings and aspirations of students.

5. Parents' Occupation and aspirations

In this study Parents' Occupation was mentioned as fathers' occupation and mothers' occupation. The 'r' value of 0.07 from table 13 revealed that there is no significant relationship between fathers' occupation and aspirations of post graduate students. The 'r' value of -0.13 from table 13 indicated that the correlation between mothers' occupation and aspirations of post graduate students was found to be negative and non-significant, meaning that it had no impact on aspirations of post graduate students.

It was observed that slightly more than half of the fathers' of post graduate student occupation was service and slightly more than one-third (35.83 per cent) of them were involved in farming, whereas 70.83 per cent mothers' had no occupation. Thus, there is no much variation in the parents' occupation further whatsoever, little variation in the present occupation is noticed, that might not have been strong enough to decide the aspiration level of the post graduate students. So also, aspiration being the personal psychological trait of the post graduate students, might not have been remarkably influenced by their parents' occupation. Rashmi (2005) observed a non-significant relationship between family occupation and aspirations.

6. Family annual income and aspirations

The family annual income operationally included the annual income of both father and mother. The 'r' value 0.23 from table 13 revealed that there was positive and significant relationship at 1.00 per cent level of significance between fathers' annual income and aspirations of the post graduate students, meaning that fathers' annual income had great impact on aspirations of post graduate students.

The 'r' value -0.14 from table 13 revealed that there was negative relationship between mothers' annual

income and aspirations of post graduate students. It was observed that seven out of ten mothers' of post graduate students had no occupation and only two out of ten mothers' were engaged in different services. Hence it can be inferred that the mothers' annual income had no impact on aspirations of post graduate students. The findings were similar with the study conducted by Saritha (2000).

CONCLUSION

The findings presented in this paper revealed that the some personal characteristics had significant and some other had non significant relationship. Hence the same type of researches can be taken up by adding some other variables which could really contribute to enhancing of the aspirations of the post graduate students.

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DEVELOPMENT AND EVALUATION OF AMARANTH BASED NUTRIENT RICH SNACK BARS

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ABSTRACT

In the present study, grain amaranth based snack bars were prepared and evaluated for its nutrient and sensory status. Apart from the basic recipe (jaggery), the experimental bar contains ingredients like pumpkin seeds, sesame seeds, tofu, groundnuts and gum acacia, respectively. Basic and experimental bars have been evaluated for the nutrient and sensory parameters using standard analytical methods. Shelf life, change in acceptability and microbiological quality have been assessed by packing the bars in HDPE and LDPE covers and storing at room temperature for one month. The results indicated that the experimental product had better texture than the basic product apart from maintaining rich moisture (4.1%), protein (4.1%), and fat (2.84%), respectively. The evaluation results of sensory parameters inferred that there was no significant change in taste, color and flavour in respect of basic and experimental bars during the entire storage period. The experimental sample was found to have better acceptability for both fresh and stored products. Microbial analysis indicated that TBC, TMC and mould count in the fresh and stored basic bars was 10 cfu / g, where as the experimental bars had the counts below detectable levels (BDL). From the study, it can be concluded that the value added amaranth based nutritious bar could be very useful in supplementing some of the nutrients for school age and adolescent group.

KEYWORDS: Amaranth based grain bar, Dietary supplementation, Nutrient content, Sensory evaluation.

INTRODUCTION

Several food based strategies and techniques have been developed in India for combating malnutrition in terms of dietary modification, supplementation and fortification (Jessica and varma *et al.*, 2007; Carle and Hasler, 2002). The methods used for supplementation or fortification should be such that it should allow nutritional benefit, convenient and appealing as a food item. In this connection, grain bars have an advantage over other food items used for supplementation, in which a bar can come in handy when there is no time to sit down and eat a food item as in case of school children, college going adolescents, working men or women and sport persons. Food bars, are the snack foods that contains good sensory characteristics, contributing rich contents of protein, lipids and carbohydrates. The development of food bars can be carried out through blending the grains, nuts and other ingredients along with some binding material like gums, liquid glucose and sucrose etc. The mixture is then shaped into a bar by passing through a roller (Al-Hooti *et al.*, 1997) or baked in a baking oven at moderate heat i.e. below 150°C (Brisske *et al.*, 2004).

Whole cereal grains can be popped, toasted or roasted and incorporated in to the shape of bar. Many of these bars have been developed to provide a specific nutritional need. A good nutrition bar has a balanced formula of nutrients viz. 10 to 15 g of protein, 20 to 30 g of carbohydrate, and 5 to 7 g of fat. (Donald and Kasarada, 2000.) A nutrition bar attempts to provide nutritional benefit to the body that is appealing and convenient as a food item.

Grain amaranth is a versatile pseudo cereal with diverse food uses with greatest benefit being its nutritional value. It is very high in protein compared to other grains such as corn and oats. It is also rich in calcium, vitamin B5, magnesium, and iron. Amaranth is high in lysine, a limiting amino acid as in other cereals and millets. Though several types of snack bars are made and sold in to cater the need of different segments of population in developed countries, great advances in this area have not been attempted in developing countries like India. Therefore, attempts can be made for making nutritious bars in India for sustaining the health of individuals. Keeping in view, the need for developing value added, ready to eat snack bars using different functional foods for combating or

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preventing malnutrition in different segments of population, the present study has been formulated to develop and evaluate amaranth based nutritious snack bars for the supplementing adolescence and sport persons.

MATERIALS AND METHODS

The study was conducted at Post Graduate Research Centre, College of Home Science, Rajendranagar, Hyderabad. All the ingredients used for preparation of the product were procured from the local super market. Amaranth seeds, Pumpkin seeds, Sesame, Ground nuts, Jaggery were cleaned to remove the extraneous matter. The amaranth seeds were popped by dry hot air popcorn popper at a temperature of 180°C. Tofu was cleaned in a running tap water to remove other particles and stored at freezer temperature. Acacia gum was powdered and then stored at room temperature. Basic recipe and different formulations used for preparing the bar is presented in Table 1.

Sesame, tofu, pumpkin and groundnut seeds were coarsely powdered and mixed together. Jaggery was dissolved in hot water and strained. Powdered gum acacia was added to it and then cooked to a soft ball stage. The mixture along with popping amaranth seeds was added to the cooked syrup and mixed thoroughly. The mixture was poured on pre greased surface and rolled out. It was allowed to set and then cut into shape of bar of 3/4 cm thickness. The bars were then packed into Low Density Polyethylene and High Density polyethylene covers.

Fresh basic and experimental products were evaluated for their organoleptic properties and textural character. Sensory evaluation was done to assess the acceptability by a panel of 20 judges. The panel members were selected from the staff of the Department of Food and Nutrition, College of Home Science and students from PGRC (Post Graduate Research Centre) Rajendranagar, Hyderabad. A score card was prepared, keeping in view of the quality characteristics of the product under study. The various evaluation parameters studied were colour, appearance, texture, taste and overall acceptability. A five point hedonic scale i.e. from 1-5 was prepared to rank each parameter with 5 point being assigned to the highly acceptable parameter.

Standard AOAC (2005) procedures were followed to estimate the proximate composition of the developed products. Samples were analysed in triplicates for moisture, protein, fat, ash, iron and calcium contents.

Moisture was estimated by hot air oven. Protein was estimated by leco protein Analyser of Model No:FP-528(USA). Fat was estimated by Soxtherm, Model No:1029(India) using the method of AOAC(1997). Ash was determined by Fibretherm, Model No:FT-12(India). Energy and crude fibre content was calculated by using the procedures laid out in Nutritive Value of Indian Foods by Gopalan *et al.* (2007). Iron and calcium were estimated by using the Flame technique in an Atomic Absorption Spectrophotometer (A700, Perkin Elmer, USA) using the method of AOAC (1990). In addition, grain bar was microbiologically evaluated for Total Bacterial Count and Total Mould Countcount at 0 day, 15th day and 30th day using the procedures laid down by Cruikshank *et al.* (1975).

Basic and experimental products were studied for their storage stability after packing in two different packing materials i.e. LDPE, HDPE. The products were initially wrapped in layer of butter paper and then packaged in different packaging materials. The packaged products were stored at room temperature. Sensory evaluation was carried out for the stored products at 0 day, 15th day and 30th day. A group of panel members consisting of staff and students of Department of Food & Nutrition (n=20) evaluated the fresh products also evaluated the stored products 0 day 15th day &30th day. The mean scores, standard error and critical difference for all the parameters were calculated using the ANOVA and T-test.

RESULTS AND DISCUSSION

Nutrient composition

The results obtained for assessing various nutrient status components are presented in Table 2.

From the table, it can be said that the moisture content of basic bar was found to be 3.8 %. On the other hand, it was 4.1% for the experimental bar. A significant increase in the moisture was found in the sample of experimental bar prepared from popped amaranth seeds which may be due to addition of more jiggery and other ingredients in experimental bars. The moisture content may be showing increased. The protein content was found to be 9.70 g in basic bar and 10.3 g in the experimental bars respectively. A significant increase of protein levels in the experimental bars by addition of sesame seeds, pumpkin seeds, ground nuts and tofu. The obtained results are in conformity with the reported results of the study conducted by Ogle and

Table 1. Ingredients in the preparation of the basic and experimental bars

Ingredient	Basic recipe	Trial-1	Trial-2	Trial-3	Final composition
Popped amaranth seeds	60 g	60 g	50 g	43 g	50 g
Pumpkinseeds	6 g	7 g	7 g	10 g	8 g
Sesame	5 g	5 g	5 g	5 g	5 g
Tofu	7 g	7 g	6 g	10 g	5 g
Ground nuts	5 g	5 g	5 g	5 g	5 g
Jaggery	15 g	7 g	25 g	25 g	25 g
Sugar	-	7 g	-	-	-
Binding-agent	2 g	2 g	2 g	2 g	2 g

Table 2. Results of proximate analysis of the snack bars (per 100 g of product)

Variable	Basic	Experimental	T-value
Moisture, %	3.8 ± 1.7	4.1 ± 5.77	12.18261**
Protein, g	9.70 ± 0.10	10.27± 0.01	14.46303**
Fat, g	2.6 ± 1.3	2.8±0.12	2.750034*
Energy, k cal	340.6*	341.2*	
Crude fibre, g	5.7*	5.3*	0.6181846
Ash, g	2.21 ± 0.3	2.8 ± 0.12	
Calcium, mg	472.24 ± 0.14	473.09 ± 0.44	4.770438**
Iron, mg	11.28 ± 0.28	16.35 ± 0.31	31.6416**

Grivetti (1985). The fat content of basic bar was found to be 2.6 g, where as for experimental bar, it was found to be 2.8 g. The obtained fat content values are less compared to other studies, due to the difference of grain and the ingredients used. The ash content of the basic bar was found to be 2.2 g, where as in the experimental bar, it was found to be 2.28 g respectively which is higher. The calcium content in basic bar was found to be 472.2 mg, where as in the experimental bar, it was 473.09 mg. The iron content in basic bar was found to be 11.5 mg, where as in the experimental bar, it was 16.35 mg.

The scores for colour of the bars ranged from 3.5 to 4.5 and texture 3.2 to 4.2 respectively on hedonic scales. The scores for flavour, taste, and overall acceptability ranged from 2.4 to 4.3, 2.7 to 4.5 and 3.9 to 4.9. All the parameters were highly rated by all the panellists for

experimental bars than control bars. The experimental bar was best accepted with highest total mean score ($p>0.05$)

The two products i.e. experimental and basic bars were kept for storage after packing in LDPE and HDPE, and kept at room temperature for testing the sensory characters of the products on storage for one month. Products were evaluated for microbial quality and for sensory quality. The sensory parameters were evaluated periodically 0 day, 15th day and 30th days using hedonic rating on a scale of 5 points. Microbiological quality for TBC and TMC was assessed at the beginning and at the end of the storage period.

There was no significant change in taste, texture, colour, flavour and overall acceptability of both the basic and experimental bars during the entire storage period.

Development of Amaranth based snack bars

The interaction between treatments and packaging material was found to be non-significant ($p > 0.05$) during storage period on overall acceptability of grain bars. Microbial analysis indicated that TBC, TMC and mould count in the fresh bars was 10cfu / g for the basic product where as the 10 cfu/g experimental bars had these counts below detectable levels (BDL).

From this study, it can be inferred that there is an advantage in the experimental bar which is nutritionally better as compared to basic samples. These bars can be recommended, mostly for anaemic patients and different age groups like adolescents, sports persons etc., wherein there is a need for nutrient supplementation. Moreover, it can be used as breakfast bars, meal replacement bars, “instant energy” bars for sports persons. Overall, it is concluded that the prepared snack grain bar made from amaranth seed is nutritious, gives instant energy, especially to eradicate alarming anaemia problem prevailed in lactating woman.

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PRUNING AND PACLOBUTRAZOL INDUCED CHANGES ON FRUIT YIELD AND FRUIT QUALITY IN MANGO (*Mangifera indica* L.)

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ABSTRACT

A study was conducted to evaluate the effects of pruning (current or previous season's vegetative growth) and paclobutrazol (PBZ) @ 3 ml m⁻¹ canopy diameter on the fruit yield and fruit quality of mango cvs. Raspuri, Dashehari and Amrapali during 2013-2014. Trees pruned to current season's growth recorded 53.4, 17.3 and 11.8 per cent higher yields than unpruned trees. Similarly application of PBZ recorded 242.4, 163.1 and 52.8 per cent more number of fruits per tree, 13.4, 14.8 and 26.1 per cent decline in average fruit weight, and 171.2, 180.0 and 49.3 per cent higher yields than control trees of Raspuri, Dashehari and Amrapali respectively, when compared to control. Among the interaction effects, trees pruned to current season's growth and with PBZ application recorded significantly higher fruit number (143.7) and higher yields per tree (28.1 kg). Raspuri and Dashehari trees pruned to current season's growth recorded high TSS (20.13 and 20.16 °Brix, respectively) compared to control trees (P₃). Similarly, trees without PBZ application (C₂) recorded higher TSS of 19.89 and 21.25 °Brix in cvs Raspuri and Dashehari, respectively. PBZ application recorded significantly higher ascorbic acid and carotenoid contents in Dashehari and Amrapali cultivars. The effects of PBZ alone or in combination with pruning were nonsignificant with respect to total sugars, nonreducing sugars and reducing sugars. The study indicated that, the responses of pruning and PBZ treatments varied with the bearing habit of the cultivars. Pruning of current season's growth and application of PBZ treatment was more pronounced in influencing the fruit yield and fruit quality of alternate bearing cultivars of Raspuri and Dashehari.

KEYWORDS: Mango, Pruning, Paclobutrazol, Fruit yield, Fruit quality

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the important tropical fruit crops grown in both tropical and subtropical regions of India for its delicious taste, excellent flavor and nutritive value. More than thousand cultivars exist in India (Dinesh, 2014), among which about 30 cultivars are commercially grown with varied production potentials. India ranks first in mango production, contributing 45.5 per cent total world's mango production (Anon, 2013). Although India is the largest producer of mango, its productivity is very less compared to Israel's productivity (30 tonnes ha⁻¹) and its share in export market is comparatively less due to inferior fruit quality. Besides alternate bearing, overcrowding of branches is one of the reasons for low productivity and poor fruit quality (Balamohan and Gopu, 2014). Pruning and application of growth retardants like paclobutrazol (PBZ) are the important strategies recommended in many fruit crops, including mango for controlling the tree vigour, promoting flowering, and enhanced production efficiency. Pruning is an effective means of maintaining canopy architecture

in order to achieve optimum productivity of superior quality fruits (Singh *et al.*, 2009). Most of the pruning studies in mango were targeted to get early and uniform flowering and to rejuvenate the senile and old trees. Similarly, PBZ is the most promising and widely used growth retardant in mango for regular and increased production. Although, the effects of PBZ on tree vigour, flowering and fruit yield are well documented (Abdel Rahim *et al.*, 2011, Upreti *et al.*, 2013); the effects of PBZ on fruit quality are limited with reference to Indian mango cultivars. Limited studies have been carried on the efficiency of combined effects of pruning and PBZ in mango. In the studies made earlier reported that, pruning in combination with PBZ is effective in influencing the tree growth and development of different mango cultivars and the response was cultivar dependent (Srilatha *et al.*, 2015). In the present investigation we reported the effects of pruning and PBZ on fruit yield and fruit quality attributes in three mango cultivars differing in their bearing habits.

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MATERIALS AND METHODS

The investigation was conducted during the year 2013-2014 at the experimental farm of Indian Institute of Horticultural Research, Bengaluru on 4 years old trees of three mango cultivars namely Raspuri (early and alternate bearing), Dashehari (late and alternate bearing) and Amrapali (late and regular bearing hybrid) raised on Olour rootstock and maintained at 7 × 7 m spacing. The experiment was laid out with three replications in a factorial randomized block design with various combinations of pruning (current season's growth, previous season's growth and no pruning) and PBZ application (0.75 g a.i./m canopy diameter and no PBZ). Each variety had a total of 36 plants (2 plants in each replication) under different treatment combinations. Pruning was carried out by removing tree branches according to the pruning level during 3rd week of July, 2013. PBZ (25% w/v a.i., Zeneca Limited, Surry, UK) was applied once as soil drench during the last week of September, 2013 by spreading in a circular band of 25 cm width at a radial distance of 75 cm from the tree trunk. Only water was used for the PBZ untreated trees. During the experimentation, the average maximum and minimum temperatures were 29.4 and 19.0°C respectively, relative humidity 74.5 per cent and total rainfall 732.7 mm.

After the emergence of new shoots, 50 shoots were tagged in all the directions of tree for recording data on yield parameters. Observations on number of fruits per plant, average fruit weight and fruit yield per plant were recorded at the time of harvesting. Fruit quality parameters such as peel weight, pulp weight and stone weight were recorded in ripened fruits by weighting the peel, pulp and stone after separating. Total soluble solids (TSS) were determined using a digital refractometer (Serie Palette, ATAGO, Japan). Total sugars content was determined by using anthrone reagent method (Dubois, 1951). Reducing sugar content was measured by following Nelsons modifications of Somogyi's method, (Somogyi, 1952) using arsenomolybdate colour forming reagent. Nonreducing sugar was obtained by subtracting reducing sugar from the amount of total sugar and multiplying the resultant by factor 0.95. Titratable acidity was determined by an acid base titration method using 0.1 N NaOH with phenolphthalein colour indicator (AOAC, 1980). Ascorbic acid content was determined with the method of AOAC (1980). Total carotenoids contents were analysed by modified method of Ranganna (1997) using acetone as

solvent and measuring the absorbance at 450 nm. All the data were statistically analyzed using Agri Stat software and the difference in the means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Fruit yield

The effects of pruning and PBZ were significant with respect to fruit number per tree, average fruit weight, yield per tree and yield per hectare in all the three cultivars. Trees pruned to current season's growth (P₁) recorded more fruit number per tree (66.5, 72.3 and 121.1) recording 53.4, 17.3 and 11.8 per cent higher yields than unpruned trees in Raspuri, Dashehari and Amrapali, respectively (Table 1). The trees pruned to previous season's growth recorded lower yields than unpruned trees in all the three cultivars. Pruning besides better light penetration, forces the early initiation of newshoots causing them to reach maturity which have the sufficient time for accumulation of photosynthates that are promotory for flowering (Oosthuysen, 1997). Pruning induced enhancement in fruit yield have been reported in different mango cultivars (Singh *et al.*, 2009). Yield reduction in trees pruned to previous season's growth than unpruned trees can be attributed to the reason that, part of photosynthates might be diverted to maintain the vegetativeness induced by pruning (Gross, 1996), further trees tends to grow vegetatively in order to replenish vegetative growth lost through severe pruning. Lower fruit yields in trees pruned to previous season's growth is in accordance with the reports of Balamohan and Gopu (2014) and Das and Jana (2012) in different mango cultivars.

Application of PBZ (P₁) recorded 242.4, 163.1 and 52.8 per cent more fruit number per tree 13.4, 14.8 and 26.1 per cent decline in average fruit weight, and 171.2, 180.0 and 49.3 per cent higher yields (Table 1) than PBZ untreated trees of Raspuri, Dashehari and Amrapali, respectively when compared to control. Decline in average fruit weight could be because of more number of fruits per tree as a result of increased flowering intensity in PBZ treated trees. PBZ induced reduction in fruit weight has also been reported by Reddy and Kurian (2008), Rebolledo-Martinez *et al.* (2008) and Reddy *et al.* (2014). In spite of the decline in average fruit weight, the higher yields in the PBZ treated trees is ascribed due to high

Table 1. Effects of pruning and paclobutrazol on yield attributes in different cultivars of mango

Treatments	Number of fruits plant ⁻¹			Average fruit weight (g)			Yield plant ⁻¹ (kg)		
	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali
Pruning									
P ₁	66.50	72.30	121.10	180.40	132.90	180.20	13.40	13.30	18.10
P ₂	43.70	45.40	64.70	187.90	146.20	192.30	8.80	7.00	17.00
P ₃	102.10	116.10	123.80	156.90	141.10	171.60	22.50	19.70	17.30
SEm±	16.96	19.87	20.51	7.53	10.29	11.34	3.33	3.33	3.12
CD at 5%	76.01	62.59	64.61	23.75	32.41	35.74	10.50	10.50	9.84
PBZ									
C ₁	109.50	112.90	124.70	162.40	128.80	154.20	21.70	19.60	20.90
C ₂	32.00	42.90	81.60	187.70	151.30	208.60	8.00	7.00	14.00
SEm±	13.85	16.22	16.74	6.15	8.40	9.26	2.72	2.72	2.55
CD at 5%	62.06	51.11	52.76	19.39	26.46	9.18	8.58	8.58	8.03
P × PBZ									
P ₁ C ₁	146.70	119.30	154.30	166.40	122.10	134.80	28.10	22.10	22.60
P ₁ C ₂	29.30	25.20	87.80	194.40	143.80	225.50	5.40	4.50	13.50
P ₂ C ₁	78.00	84.00	70.70	159.20	133.40	167.90	15.70	12.80	19.50
P ₂ C ₂	9.30	6.70	58.70	216.60	158.90	216.60	1.90	1.20	14.50
P ₃ C ₁	103.70	135.50	149.20	161.70	130.90	159.50	21.30	24.00	20.60
P ₃ C ₂	57.50	96.70	98.30	152.20	151.30	183.60	16.80	15.30	14.00
SEm±	23.98	28.10	29.00	10.66	14.55	16.04	4.71	4.71	4.41
CD at 5%	107.49	NS	NS	33.58	NS	NS	11.01	NS	NS

P - Pruning, PBZ - Paclobutrazol

P₁ - pruning of current season's growth C₁ - PBZ @ 3 ml m⁻¹ canopy spreadP₂ - pruning of previous season's growth C₂ - no PBZP₃ - no pruning

Table 2. Effect of pruning and paclobutrazol on fruit quality in different cultivars of mango

Treatments	Number of fruits plant ⁻¹			Average fruit weight (g)			Yield plant ⁻¹ (kg)		
	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali
Pruning									
P ₁	31.04	28.41	31.91	117.43	79.47	118.89	27.20	25.04	29.38
P ₂	55.12	32.52	31.04	100.60	89.50	132.13	32.42	24.15	29.08
P ₃	35.04	27.63	27.12	102.44	79.92	114.48	24.35	23.60	29.94
SEm±	1.94	3.50	1.49	6.83	6.98	12.42	0.93	1.06	2.43
CD at 5%	6.11	NS	NS	NS	NS	NS	2.95	NS	NS
PBZ									
C ₁	31.43	28.26	25.53	108.49	76.89	100.74	28.10	23.64	27.81
C ₂	49.37	30.77	34.51	105.15	89.03	142.92	27.87	24.87	31.12
SEm±	1.58	2.85	1.22	5.57	5.70	10.14	0.76	0.86	1.98
CD at 5%	4.99	NS	3.84	NS	NS	31.97	2.41	NS	NS
P × PBZ									
P ₁ C ₁	29.44	25.96	22.87	125.11	73.07	88.42	29.43	23.00	23.51
P ₁ C ₂	32.63	30.85	40.94	109.75	85.87	149.36	24.96	27.07	35.24
P ₂ C ₁	35.25	30.65	27.37	95.21	77.96	110.08	28.90	24.80	30.48
P ₂ C ₂	74.99	34.39	34.7	105.98	101.04	154.17	35.93	23.49	27.68
P ₃ C ₁	29.60	28.17	26.36	105.15	79.64	103.72	25.98	23.13	29.43
P ₃ C ₂	40.48	27.08	27.88	99.73	80.19	125.23	22.71	24.06	30.45
SEm±	2.74	4.94	2.11	9.65	9.88	17.57	1.32	1.50	3.43
CD at 5%	8.64	NS	6.66	NS	NS	NS	4.18	NS	NS

P - Pruning,
P₁ - pruning of current season's growth
P₂ - pruning of previous season's growth
P₃ - no pruning

PBZ - Paclobutrazol
C₁ - PBZ @ 3 ml m⁻¹ canopy spread
C₂ - no PBZ

Table 3. Effect of pruning and paclobutrazol on fruit quality in different cultivars of mango

Treatments	Number of fruits plant ⁻¹				Average fruit weight (g)				Yield plant ⁻¹ (kg)				
	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Raspuri	Amrapali	Dashehari	Raspuri	Amrapali	Dashehari	Raspuri	Amrapali
Pruning													
P ₁	20.13	20.16	20.58	163.15	119.85	161.95	161.95	40.75	43.54	43.20	43.54	43.20	43.20
P ₂	18.58	20.29	22.83	165.05	115.05	164.65	164.65	37.06	43.36	42.85	43.36	42.85	42.85
P ₃	18.17	20.03	22.38	165.55	106.75	163.30	163.30	38.04	43.03	43.63	43.03	43.63	43.63
SEm±	0.16	0.54	1.48	1.70	5.05	2.43	2.43	1.49	1.32	2.91	1.32	2.91	2.91
CD at 5%	0.52	1.70	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PBZ													
C ₁	18.03	19.07	20.38	162.67	112.93	163.17	163.17	38.26	44.64	44.93	44.64	44.93	44.93
C ₂	19.89	21.25	23.48	166.50	114.83	163.43	163.43	38.97	41.97	41.52	41.97	41.52	41.52
SEm±	0.13	0.44	1.20	1.39	4.12	1.99	1.99	1.21	1.07	2.37	1.07	2.37	2.37
CD at 5%	0.42	1.39	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P × PBZ													
P ₁ C ₁	19.00	18.31	17.33	160.70	112.60	163.10	163.10	39.41	45.58	45.45	45.58	45.45	45.45
P ₁ C ₂	21.25	22.00	23.83	165.60	127.10	160.80	160.80	42.08	41.49	40.95	41.49	40.95	40.95
P ₂ C ₁	17.33	19.25	22.16	162.50	113.40	165.00	165.00	35.04	44.35	45.58	44.35	45.58	45.58
P ₂ C ₂	19.83	21.33	23.50	167.60	116.70	164.30	164.30	39.08	42.37	40.12	42.37	40.12	40.12
P ₃ C ₁	17.75	19.65	21.66	164.80	112.80	161.40	161.40	40.33	44.00	43.75	44.00	43.75	43.75
P ₃ C ₂	18.58	20.41	23.10	166.30	100.70	165.20	165.20	35.74	42.05	43.50	42.05	43.50	43.50
SEm±	0.23	0.76	2.09	2.40	7.14	3.45	3.45	2.11	1.86	4.12	1.86	4.12	4.12
CD at 5%	0.74	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P - Pruning, PBZ - Paclobutrazol
P₁ - pruning of current season's growth C₁ - PBZ @ 3 ml m⁻¹ canopy spread
P₂ - pruning of previous season's growth C₂ - no PBZ
P₃ - no pruning

Table 4. Effect of pruning and paclobutrazol on fruit quality attributes in different cultivars of mango

Treatments	Number of fruits plant ⁻¹			Average fruit weight (g)			Yield plant ⁻¹ (kg)		
	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali	Raspuri	Dashehari	Amrapali
Pruning									
P ₁	2.38	1.38	1.25	0.41	0.33	0.57	0.123	0.113	0.148
P ₂	2.13	1.38	1.50	0.39	0.32	0.59	0.113	0.092	0.149
P ₃	2.06	1.50	1.25	0.41	0.33	0.59	0.143	0.111	0.154
SEm±	0.14	0.14	0.24	0.02	0.01	0.02	0.014	0.066	0.011
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
PBZ									
C ₁	2.12	1.25	1.25	0.42	0.35	0.58	0.128	0.121	0.157
C ₂	2.25	1.58	1.42	0.38	0.30	0.58	0.124	0.089	0.143
SEm±	0.11	0.12	0.20	0.02	0.01	0.02	0.011	0.054	0.095
CD at 5%	NS	0.38	NS	NS	0.03	NS	NS	0.017	0.030
P × PBZ									
P ₁ C ₁	2.50	1.25	1.25	0.42	0.36	0.57	0.124	0.133	0.164
P ₁ C ₂	2.25	1.50	1.25	0.39	0.30	0.57	0.122	0.093	0.131
P ₂ C ₁	2.00	1.25	1.25	0.42	0.33	0.57	0.109	0.099	0.153
P ₂ C ₂	2.25	1.50	1.75	0.36	0.30	0.60	0.117	0.084	0.144
P ₃ C ₁	1.87	1.25	1.25	0.42	0.36	0.60	0.151	0.130	0.155
P ₃ C ₂	2.25	1.75	1.25	0.39	0.30	0.57	0.134	0.091	0.153
SEm±	0.20	0.20	0.35	0.03	0.01	0.03	0.020	0.094	0.016
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

P - Pruning,
P₁ - pruning of current season's growth
P₂ - pruning of previous season's growth
P₃ - no pruning
PBZ - Paclobutrazol
C₁ - PBZ @ 3 ml m⁻¹ canopy spread
C₂ - no PBZ

flowering intensity which resulted from higher fruit number. PBZ has been reported to alter source and sink relationship and exert influence on partitioning the photosynthates to the sites of flowering and fruit production with a reduction in vegetative growth (Kurian *et al.*, 2001). Yield advantage following PBZ application was in agreement with the findings of Upreti *et al.* (2013) and Sarkar and Rahim (2012) in different mango cultivars. Similarly, the interaction effect of pruning and PBZ was significant only in cv. Raspuri. Unpruned trees of Raspuri with application of PBZ (P₃C₁) recorded more fruit number per plant (146.7) followed by 103.7 fruits in trees pruned to current season's growth and with application of PBZ (P₁C₁). The cumulative effect of pruning and PBZ is expected to enhance the yields as evident from the results.

Fruit quality parameters

The effects of pruning and PBZ were significant on peel weight and stone weight in cv. Raspuri only. However, effects of pruning, PBZ and the interaction effects of pruning and PBZ were found non-significant with respect to pulp content in all the three cultivars (Table 2). PBZ treated trees of Raspuri recorded 7.24 per cent decline in peel weight than PBZ untreated trees. Growth retardants affect the peel weight to some extent directly or indirectly through their effect on cell division and cell expansion could be the reason for less peel content in fruits of PBZ treated Raspuri trees. PBZ induced decrease in peel content and increase in pulp content is also reported in litchi (Rani and Bramhachari, 2000).

Effects of pruning and PBZ on TSS were significant in Raspuri and Dashehari cultivars and their interaction effects were significant only in Raspuri (Table 3). Raspuri and Dashehari trees pruned to current season's growth recorded high TSS (20.13 and 20.16 °Brix, respectively), while the lower TSS was recorded in unpruned control trees (P₃). Similarly trees without PBZ application (C₂) recorded higher TSS of 19.89 and 21.25 °Brix in cvs Raspuri and Dashehari, respectively. Interaction effect was significant only in cv. Raspuri. Highest TSS (21.25 °Brix) was recorded in trees pruned to current seasons's growth with out PBZ (P₁C₂) followed by 19.83 °Brix in trees pruned to previous season's growth without PBZ application (P₂C₂). Higher TSS in trees pruned to current season's growth than previous season's growth treatments could be due to availability of more carbohydrates among the sink in trees pruned to current season's growth.

Ascorbic acid and carotenoid contents differed significantly only with PBZ in Dashehari (Table 4). Dashehari trees with application of PBZ (C₁) recorded higher ascorbic acid content (0.35 mg g⁻¹) and highest total carotenoids (0.121 mg g⁻¹) than PBZ untreated trees. Similarly PBZ application recorded higher carotenoid contents (0.157 mg g⁻¹) in Amrapali, than control trees. Increase in the contents of ascorbic acid and carotenoids, and reduction in acidity with PBZ application in Dashehari and Amrapali cultivars indicated the improvement in the fruit quality, as they are documented as potential antioxidants. The increase in TSS, ascorbic acid and reduction in acidity due to the application of PBZ in the present investigation might be because of accumulation of more minerals and carbohydrates (Vijaylakshmi and Srinivasan, 2000). Effectiveness of PBZ in enhancing the ascorbic acid and carotenoids have also been reported in mango (Reddy *et al.*, 2014), papaya (Auxilia *et al.*, 2010) and guava (Jain and Dashora, 2011).

The study indicated that, the effects of different treatments on fruit yield and fruit quality varied with bearing habit of cultivars. Pruning of current season's growth and application of PBZ @ 0.75 g a.i./m canopy diameter was more pronounced in alternate bearing cultivars Raspuri, and Dashehari as compared to regular bearing hybrid Amrapali.

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Pruning and paclobutrazol induced changes on mango yield

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TRAIT ASSOCIATION STUDIES FOR YIELD, DROUGHT AND THEIR COMPONENT TRAITS IN MUNGBEAN (*Vigna radiata* (L.) WILCZEK)

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ABSTRACT

An experiment to know the nature and magnitude of association among various yield and drought related traits and their contribution towards seed yield was carried out with thirty five mungbean genotypes during *khari*f, 2014-15. Estimates of correlations revealed that seed yield had positive and significant correlation with number of pods per plant, number of clusters per plant, number of seeds per pod, 100 seed weight, relative water content and SCMR, which indicated that improvement in seed yield coupled with drought tolerance in greengram could be brought through selection of component characters like number of pods per plant, number of clusters per plant, number of seeds per pod, 100 seed weight, SCMR and relative water content.

Keywords: Mungbean, drought and correlation

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse legume and ranks third after chickpea and pigeon pea in India. It is a cheap and rich source of vegetable protein, and therefore, commonly used as a supplement to the normal diet of many people. Mungbean occupies an important position due to its suitability to various agro-climatic conditions, rich in essential aminoacids specially lysine, high seed protein content (22 to 24%) and ability to restore the soil fertility through symbiotic nitrogen fixation. Despite its importance in several aspects, the mungbean yields are considered to be low and needs to be improved to meet its demand. However, the productivity in mungbean is being hampered by different biotic and abiotic stresses of which drought could be considered as the major one. Since seed yield and drought tolerance are complex in nature and expression of these traits are largely depends upon the interplay of a number of component traits, knowledge of associations of these traits on various component traits is always helpful. Hence, the present investigation is aimed at estimating the correlation coefficients of a number of yield and drought related components in mungbean with an objective to develop high yield coupled with drought tolerant genotypes.

MATERIAL AND METHODS

The experimental material comprised at thirty five diverse genotypes of mungbean. All these thirty five genotypes were evaluated using randomized block design

(RBD) with three replications during *khari*f, 2014-15 at dry land farm, Sri Venkateswara Agricultural College, Tirupati.

The inter and intra- row spacing adapted was 30cm x 10cm. Each genotype was sown in three rows of 4m length and observations were recorded on five randomly selected plants of each genotype in each replication for the characters *viz.*, plant height, number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, hundred seed weight, harvest index, SPAD Chlorophyll Meter Reading (SCMR), Relative Water Content (RWC), Relative Injury (RI), Specific Leaf Area (SLA) and seed yield per plant. However, the data for days to 50% flowering and days to maturity were recorded on plot basis. Recommended cultural practices and plant protection measures were followed to raise a healthy crop. Genotypic and phenotypic correlations were calculated as per the procedure described by Johnson *et al.*, (1955).

RESULTS AND DISCUSSION

Analysis of variance revealed that the genotypes differed significantly for all the characters indicating the existence of considerable amount of variation among the genotypes studied (Table 1) and hence the data were subjected to analysis of genotypic and phenotypic correlations. The phenotypic and genotypic correlation coefficients between all pairs of characters were presented

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Table 1. Analysis of variance for fourteen quantitative characters in thirty five genotypes of mungbean

Sl. No.	Characters	Mean sum of squares		
		Replications (df: 2)	Treatments (df: 34)	Error (df: 68)
1.	Days to 50% flowering	0.58	15.88**	1.22
2.	Days to maturity	2.08	12.41**	1.33
3.	Plant height (cm)	21.72	67.51**	7.21
4.	No. of clusters per plant	0.11	4.14**	0.27
5.	No. of pods per cluster	0.31	0.37**	0.09
6.	No. of pods per plant	4.60	41.73**	5.28
7.	No. of seeds per pod	0.56	0.79**	0.12
8.	100 seed weight (g)	0.04	1.69**	0.08
9.	Harvest index (%)	6.45	53.07**	3.34
10.	SPAD Chlorophyll Meter Reading	5.58.	31.61**	2.74
11.	Relative water content (%)	0.18	35.94**	2.65
12.	Specific leaf area (cm ² g ⁻¹)	59.68	2556.38**	50.69
13.	Relative injury (%)	177.11	376.67**	8.13
14.	Seed yield per plant (g)	0.17	5.18**	0.11

** : Significant at 1% level

in Table 2. The perusal of the data indicated that the genotypic correlations were greater than the corresponding phenotypic correlations in all most all the cases, indicating the preponderance of genetic variance in expression of different characters (Table 2). Genetic correlation between different characters of plant could arise because of linkage, pleiotropy or developmentally induced functional relationships. Seed yield per plant possessed highly significant positive correlation with number of clusters per plant, number of pods per plant, number of seeds per pod, 100 seed weight, SCMR and relative water content. This indicates that selection based on these characters may result in yield improvement under drought conditions. Similar kind of results were also reported by Reddy *et al.* (2011), Khanpara *et al.* (2012) and Swathi (2013).

The inter-se correlations among yield and drought related traits were also studied and found that, days to 50% flowering showed positive association with days to maturity and plant height. Similarly, days to maturity with plant height; number of clusters per plant with number of pods per plant; Number of pods per cluster with number of pods per plant; Number of pods per plant with relative water content; 100 seed weight with SCMR; harvest index with SCMR and SCMR with relative water content showed positive and significant association suggesting the interdependency of these characters on each other.

Days to 50% flowering had positive and significant association with days to maturity at both genotypic and phenotypic levels and is of an important component in identifying and deciding the duration of the crop. Thus, it indicated that flowering time was an important indicator of maturity. Both these traits *i.e.* days to 50% flowering and days to maturity were also found to have positive and significant correlations with plant height and negative associations with 100 seed weight and seed yield per plant.

Hence, such type of associations could be exploited for development of high yield coupled with early types. These results were also observed by Swathi (2013) and Rekha (2014). In case of drought related traits, SCMR had significant positive correlation with relative water content and negative correlation with specific leaf area.

By and large, from the present study it is evident that improvement in seed yield coupled with drought tolerance in green gram could be brought through selection of component characters like number of clusters per plant, number of pods per plant, number of seeds per pod, 100 seed weight, SCMR and relative water content, which showed highly significant positive association with seed yield.

Table 2. Phenotypic (r_p) and genotypic (r_g) correlation coefficients among fourteen characters in thirty five genotypes of mungbean

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of clusters plant ⁻¹	No. of pods cluster ⁻¹	No. of pods plant ⁻¹	No. of seeds pod ⁻¹	100 seed weight (g)	Harvest index (%)	SCMR	Relative water content (%)	Specific leaf area (cm ² g ⁻¹)	Relative injury (%)	Seed yield plant ⁻¹ (g)
Days to 50% flowering	r_p	1.000	0.974**	0.127	0.079	0.072	0.098	-0.455**	-0.076	-0.250*	-0.405**	0.059	-0.258**	-0.312**
	r_g	1.000	0.636	0.136	0.040	0.077	0.133	-0.465	-0.074	-0.245	-0.435	0.064	-0.264	-0.329
Days to maturity	r_p	1.000	0.578**	0.119	0.110	0.074	0.151	-0.466**	-0.071	-0.204*	-0.362**	0.021	-0.220*	-0.275**
	r_g	1.000	0.651	0.128	0.091	0.084	0.189	-0.481	-0.072	-0.198	-0.401	0.031	-0.225	-0.288
Plant height (cm)	r_p	1.000	1.000	0.163	-0.006	0.103	0.060	-0.302**	-0.342**	0.022	-0.057	0.128	-0.179	-0.017
	r_g	1.000	1.000	0.165	-0.031	0.084	0.039	-0.317	-0.388	-0.003	-0.077	0.146	-0.191	-0.018
No. of clusters plant ⁻¹	r_p	1.000	1.000	1.000	-0.172	0.616**	0.175	-0.096	-0.018	0.177	0.184	-0.085	-0.115	0.436**
	r_g	1.000	1.000	1.000	-0.220	0.652	0.178	-0.099	-0.011	0.185	0.192	-0.090	-0.122	0.451
No. of Pods cluster ⁻¹	r_p	1.000	1.000	1.000	1.000	0.394**	-0.019	-0.115	0.089	0.148	0.025	-0.129	-0.094	0.044
	r_g	1.000	1.000	1.000	1.000	0.432	-0.034	-0.125	0.163	0.202	0.021	-0.153	-0.106	0.050
No. of Pods plant ⁻¹	r_p	1.000	1.000	1.000	1.000	1.000	0.168	-0.303**	-0.001	-0.085	0.262**	-0.037	-0.118	0.342**
	r_g	1.000	1.000	1.000	1.000	1.000	0.147	-0.337	0.003	0.078	0.276	-0.030	-0.130	0.357
No. of Seeds pod ⁻¹	r_p	1.000	1.000	1.000	1.000	1.000	1.000	-0.147	-0.004	0.089	0.065	-0.135	-0.015	0.224*
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	-0.165	-0.009	0.076	0.080	-0.147	-0.013	0.230
100 seed weight (g)	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.025	0.386**	0.015	-0.196*	-0.094	0.214*
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.019	0.405	0.029	-0.203	-0.102	0.218
Harvest index (%)	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.350**	0.108	-0.326**	-0.015	0.086
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.367	0.112	-0.338	-0.024	0.098
SCMR [#]	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.260*	-0.091	0.060	0.563**
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.282	0.089	0.064	0.590
Relative water content (%)	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.056	0.083	0.577**
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.059	0.089	0.601
Specific leaf area (cm ² g ⁻¹)	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.165	-0.007
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.168	-0.006
Relative injury (%)	r_p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.058
	r_g	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.063

[#]: SPAD chlorophyll meter reading
 *, **, ***: Significant at 5% and 1% levels, respectively

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EFFECT OF NITROGEN FERTILIZATION AND TIME OF HARVESTING ON GROWTH AND YIELD OF FODDER SORGHUM

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ABSTRACT

A field experiment was conducted during *kharif*, 2013 to study the effect of different nitrogen levels and time of harvesting on yield and quality of fodder sorghum. The experiment was laid out in randomized block design with factorial concept, replicated thrice and the treatments consisted of four nitrogen levels *i.e.*, 75, 100, 125 and 150 kg ha⁻¹ and four times of harvesting *i.e.*, 45, 60, 75 and 90 days after sowing. The results revealed that the growth parameters of leaves per plant, leaf area index and green forage yield were increased significantly with the increase in nitrogen upto 150 kg ha⁻¹. Delay in harvest of fodder sorghum upto 90 days increased the leaves per plant, leaf area index and green forage yield.

KEYWORDS: Fodder sorghum, Leaves per plant, Leaf area index, Green forage yield

Sorghum is one of the important fodder crop cultivated in India and characterized by quick growth, leafiness, high green herbage yield with better palatability (George Thomas, 2003). Fodder sorghum occupies around 30 per cent of the cultivated area under forages and therefore attracts greater attention of the researcher for improvement in herbage productivity. The productivity and availability of good quality herbage is most important to fulfill the feeding requirement of dairy cattle. However, information on its agronomic aspects, especially location specific requirements is meagre. Among the various agronomic factors, proper crop nutrition and appropriate time of harvesting are of prime importance in getting higher forage yield of better quality. Of the major nutrient elements, nitrogen has special significance in increasing the green biomass yield and its quality.

MATERIAL AND METHODS

The field experiment was conducted during *kharif*, 2013 at the S.V. Agricultural College Farm, Tirupati on sandy loam soil with pH 7.1, low in organic carbon (0.42 %), low in available N (235 kg ha⁻¹), medium in available P₂O₅ (23.7 kg ha⁻¹) and medium in available K₂O (191 kg ha⁻¹). The experiment was laid out in randomized block design with factorial concept comprising of 16 treatment combinations and replicated thrice. The treatments were different nitrogen levels N₁: 75 kg ha⁻¹, N₂: 100 kg ha⁻¹, N₃: 125 kg ha⁻¹, N₄: 150 kg ha⁻¹ and different times of

harvesting T₁: 45 DAS, T₂: 60 DAS, T₃: 75 DAS, T₄: 90 DAS. Fodder sorghum Pusa chari-23 was taken as the variety. The recommended dose of 40 kg P₂O₅ and 30 kg K₂O ha⁻¹ was applied through single super phosphate and muriate of potash respectively to all the plots. As per the treatment schedule, nitrogen was applied in two equal splits, half dose of nitrogen along with full dose of phosphorus and potassium were applied as basal at the time of sowing. The remaining quantity of nitrogen was top dressed at 30 DAS. Recommended agronomic practices and plant protection measures were followed. The data on growth parameters and green fodder yield were recorded and was subjected to statistical scrutiny by the method of analysis of variance by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The different levels of nitrogen and time of harvesting exerted significant effect on growth parameters and green fodder yield of fodder sorghum. Addition of nitrogen increased the number of leaves and total leaf area per plant and their effect on enlargement of leaf cells, which resulted in assimilation of photosynthates that would ultimately result in good performance of the crop in LAI (Table 1). These findings were in conformity with the results of Verma *et al.* (2005). All harvest intervals also differed significantly from one another, plots harvested 90 DAS produced more LAI as compared to others. Increase in leaf area per plant at 90 DAS may be

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Effect of N and harvesting time on fodder sorghum

Table 1. Leaf area index of fodder sorghum as influenced by nitrogen levels and time of harvesting

Treatments		Nitrogen levels			
Time of harvesting	75 kg ha ⁻¹	100 kg ha ⁻¹	125 kg ha ⁻¹	150 kg ha ⁻¹	Mean
45 DAS	3.21	4.60	5.80	6.30	4.98
60 DAS	3.80	4.70	6.07	6.80	5.34
75 DAS	4.10	5.10	6.40	6.70	5.58
90 DAS	4.90	5.50	6.80	7.40	6.15
Mean	4.00	4.97	6.27	6.80	
		SEm±		CD (P=0.05)	
Nitrogen levels		0.08		0.23	
Time of harvesting		0.08		0.23	
Nitrogen levels × Time of harvesting		0.16		NS	

Table 2. Number of leaves per plant of fodder sorghum as influenced by nitrogen levels and time of harvesting

Treatments		Nitrogen levels			
Time of harvesting	75 kg ha ⁻¹	100 kg ha ⁻¹	125 kg ha ⁻¹	150 kg ha ⁻¹	Mean
45 DAS	8.78	8.30	8.97	10.02	10.55
60 DAS	9.87	12.15	12.74	15.55	12.09
75 DAS	11.37	13.45	16.31	17.23	13.57
90 DAS	12.19	14.45	16.25	15.05	14.49
Mean	9.02	12.28	14.59	14.46	
		SEm±		CD (P=0.05)	
Nitrogen levels		0.31		0.90	
Time of harvesting		0.31		0.90	
Nitrogen levels × Time of harvesting		0.63		2.00	

Table 3. Green fodder yield (t ha⁻¹) of fodder sorghum as influenced by nitrogen levels and time of harvesting

Treatments		Nitrogen levels			
Time of harvesting	75 kg ha ⁻¹	100 kg ha ⁻¹	125 kg ha ⁻¹	150 kg ha ⁻¹	Mean
45 DAS	11.60	12.81	14.89	16.56	14.36
60 DAS	13.70	15.92	17.25	18.36	15.94
75 DAS	15.54	16.44	18.41	19.15	17.39
90 DAS	16.58	18.59	19.00	21.74	18.95
Mean	13.97	16.31	17.39	18.98	
		SEm±		CD (P=0.05)	
Nitrogen levels		0.37		1.09	
Time of harvesting		0.37		1.09	
Nitrogen levels × Time of harvesting		0.76		2.18	

due to taking the more growing days as compared to other treatments at each delay in harvesting times. Increase in leaf area with delayed harvesting has been reported by Bukhari (2009). There was no interaction effect between nitrogen levels and time of harvesting on LAI.

Leaves have more nutritive values as compared to the stem of the plant, so, number of leaves per plant is very important parameter for calculating the growth and forage yield (Ibrahim *et al.*, 2014). Total number of leaves per plant were increased with the increment in the dose of nitrogen. Maximum number and minimum number of leaves recorded with the application of nitrogen at 150 kg N ha⁻¹ and with nitrogen at 75 kg N ha⁻¹, respectively (Table 2). The effect of nitrogen application on number of leaves plant⁻¹ showed significant effect on forage sorghum. The increase in number of leaves plant⁻¹ could be attributed to the fact that nitrogen is an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis (Tisdale *et al.*, 1995). Further, the increase in number of leaves plant⁻¹ might be attributed to the fact that photosynthesis depends largely on enzymes in which nitrogen is a major constituent. Under adequate nitrogen fertilization, fodder sorghum growth rate and the photosynthetic rate per unit area were increased and consequently higher leaf area (Nelson *et al.*, 1992). Further, nitrogen is involved in increasing the protoplasmic constituents and accelerating the process of cell division which in turn results in luxuriant vegetative growth (El-Murtada and Amin 2011). Number of leaves per plant was increased with delayed harvesting. The crop harvested at 90 DAS and 45 DAS produced maximum and minimum number of leaves, respectively. The reason of having maximum number leaves with delay in harvesting may be the increase in nodes due to more growth and plant height with time. Significant increase in number of leaves with delayed harvesting was also reported by Ayub *et al.* (2009) and Bukhari (2009). There was an interaction effect between nitrogen levels and time of harvesting. The crop fertilized with 150 kg N ha⁻¹ and harvested at 90 DAS produced maximum number of leaves per plant.

Green fodder yield per hectare was improved significantly as nitrogen level was increased from 75 to 150 kg ha⁻¹. The highest green fodder yield was produced with the application of nitrogen at 150 kg ha⁻¹ which was significantly superior to other nitrogen levels tried (Table 3). This may be due to greater plant height and stem diameter

with the increase in levels of nitrogen. Nitrogen is an integral part of chlorophyll and also an essential component of amino acids and related proteins which are critical not only as building blocks for plant tissue but also in cell nuclei and protoplasm. Further, nitrogen is essential for carbohydrates used within the plants and stimulates the growth and development as well as uptake of other nutrients. This element encourages above ground vegetative growth and this favourable impact resulted in taller plants, more number of leaves, higher total chlorophyll content, more tillers and higher dry matter accumulation might have reflected in terms of higher green fodder yields. Similar reports were given by Bishanoi *et al.* (2005). The crop harvested at 90 DAS produced significantly higher green fodder yield which was followed by crop harvested at 75 DAS. The lower green fodder yield was recorded when the crop was at 45 DAS. Increase in fodder yield with delayed harvesting was mainly due to taller plants and thicker stems. (Balasubramanian and Ramamoorthy, 1996). This might be due to longer duration which increased the growth parameters due to more sources available for the synthesis of metabolites. The interaction between nitrogen levels and time of harvesting was also significant with respect to green fodder yield. The crop received 150 kg N ha⁻¹ and harvested at 90 days after sowing produced the maximum green fodder yield. These results were in strong agreement with the conclusions of Ahmed *et al.* (2001) and Maqsood and Asif (2013).

CONCLUSION

The supply of 150 kg N ha⁻¹ and harvesting of fodder sorghum at 75 DAS is the best combination for obtaining the highest qualitative green fodder

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RELATIONSHIP OF THE PROFILE CHARACTERISTICS OF FARM WOMEN WITH THEIR MANAGERIAL ROLE

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ABSTRACT

The study was conducted in the year 2013 by using Ex-post facto research design in Chittoor district of Andhra Pradesh with a sample of 120 randomly selected farm women, which revealed that majority of the respondents were under medium managerial role category. Independent variables viz., education, extension contact, value orientation, mass media exposure, achievement motivation, innovativeness, scientific orientation and risk orientation were found to be significantly related with the managerial role. Considering the substantial role played by women farmers, the extension services should be oriented with special efforts towards them.

KEYWORDS: Managerial role, Farm Women

INTRODUCTION

The prosperity and growth of a nation depends on the status and development of women as they constitute about 50.00 per cent of the human resource of the country. Women play a significant role in agriculture and allied fields. They also perform several management and decision making roles in farming and home making practices with their male counterparts and sometimes alone (Sreenivasulu and Punnarao, 2005). Women have by and large remained as unimportant workers. Studies on women in agriculture conducted in India and other developing and under developed countries point to the fact that women contribute far more to agricultural production than has generally been acknowledged. Recognition of their crucial role in agriculture should not obscure the fact that farm women continue to be concerned with their primary functions as wives, mothers and homemakers. Justification for improving farm women's access to agricultural extension system must begin with analysis of women participation in managerial aspects of agricultural production process.

With this back ground, the present study was conducted to unearth the relationship between profile characteristics of farm women and their managerial role.

MATERIAL AND METHODS

A study was conducted by using expost-facto research design to assess the profile characteristics of farm

women in Chittoor district of Andhra Pradesh during the year 2013. Chittoor district was purposively selected for the study because maximum number of farm women were involved in agricultural operations. The researcher hailed from the same area and had the familiarity with social conditions, local language and culture of the people. Chittoor district comprises of 66 mandals out of which four mandals namely Ramachandrapuram, Vadamalapeta, Puttur and GD Nellore were purposively selected for the study as most of the farm women were involved in agricultural operations. From each of the selected mandals, two villages were selected based on random sampling procedure. Thus, totally eight villages were selected for the study. A total sample of 120 farm women were selected by selecting 15 farmers from each village through simple random sampling procedure.

Keeping the objectives of the study in view, a semi structured interview schedule was developed and pretested. This was administered to sample respondents through personal investigation. The data obtained were coded, classified and tabulated. Finally statistical tools such as arithmetic mean, standard deviation, frequency and percentage were used for the analysis of the data, so that the finding could be meaningfully interpreted and conclusions drawn.

RESULTS AND DISCUSSION

An attempt was made to understand the relation between profile characteristics of farm women and their

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Farm women profile characteristics and their managerial role

managerial role. It could be noticed from Table 1 that 55.00 per cent of the respondents were under medium level of managerial role while 23.33 per cent and 21.67 per cent were in high and low groups respectively. Thus, there is a scope to increase the farm women participation and level of farm management. The findings of Khelkar (1995) and Shilpa (2001) were in conformity with the present finding.

Table 1. Distribution of farm women based on their managerial role (n = 120)

S. No.	Category	Frequency	Percentage
1.	Low	26	21.67
2.	Medium	66	55.00
3.	High	28	23.33
Total		120	100.00

Women were consulted more for selected agricultural decisions like quantity of grains to be used and stored, getting credit and its repayment, employment of labour for operations like sowing, weeding, harvesting and buying equipment etc. Their participation in matters like adoption of practices and farm credit was found to be supportive in nature. Farm women participation was found to be better in managerial roles like planning, organizing, supervision, communication, co-ordination and controlling aspects of cultivation (Sreenivasulu and Punarnarao, 2005). With a view to understand the nature of relationship between independent and dependent variables, the data were subjected to correlation coefficient and presented in Table 2. The relational analysis revealed that the computed 'r' value of education (0.5707), extension contact (0.4650), value orientation (0.5277), mass media exposure (0.4981), achievement motivation (0.3236), innovativeness (0.5265), scientific-orientation (0.4510) and risk orientation (0.3475) were found to be significant at 0.01 level of probability. This indicates that education, extension contact, value orientation, mass media exposure, achievement motivation, innovativeness, scientific orientation and risk orientation exhibited a positive and significant relationship with managerial role of farm women.

Education is the means for development. Education facilitates for the understanding and interpretation of facts. The possible reason for the existence of positive and significant relationship between education and managerial role might be due to the fact that educated women had

more knowledge about cultivation. They were able to identify pest and disease incidences more clearly. Educated women could know the cost of cultivation of different crops. So education affects the managerial role of farm women. Sreedevi (1996) and Sreenivasulu and Punarnarao (2005) also reported similar results.

Extension agents are the best and reliable sources of information for farming community. Farm women with good extension contact have more knowledge which develops favourable attitude towards agricultural activities which in turn leads to better managerial role. Of late many government programmes were introduced keeping in view of small and marginal farmers. The extension functionaries were making efforts to meet the farmers through different agricultural programmes which were mainly focused on the poverty alleviation and improving the socio economic standards of rural poor. Hence positive and significant relationship was observed between extension contact and managerial role of farm women. This finding was in accordance with the finding of Sreedevi (1996).

Farm women who are cosmopolite, liberal and hold scientific values are likely to acquire more information on recent technologies by exposing themselves to cosmopolite and mass media sources of information and adopt new innovations. They will also be enthusiastic and self-driven to seek information on advanced technologies which facilitates adoption of advanced crop production technologies. Thus contributes to better managerial role of farm women. Hence positive and significant relationship was established between value orientation and managerial role of farm women. This finding was in conformity with the findings of Kiran (2000) and Begum (2008).

The positive relationship between mass media exposure and the managerial role of farm women might be due to increase in the telecast of agricultural programmes through different channels and number of newspapers publishing a full columns on agriculture the women farmers were becoming aware of specific practices with regard to crop cultivation and this led to the better managerial role of women farmers. In the age of the information explosion and several new technologies were being diffused into agricultural communities through mass media. Farm women with good mass media exposure are in a position to pick up right technologies at right time and implement them. Hence, this trend was noticed. The finding was in conformity with the finding of Kiran (2000) and Begum (2008).

Table 2. Relationship between selected profile characteristics of farm women and their managerial role

S. No.	Variable	Correlation co-efficient 'r' value
X ₁	Age	-0.2651**
X ₂	Education	0.5707**
X ₃	Farm size	0.0155 ^{NS}
X ₄	Family income	0.1340 ^{NS}
X ₅	Extension contact	0.4650**
X ₆	Value orientation	0.5277**
X ₇	Participation	0.1229 ^{NS}
X ₈	Mass media exposure	0.4981**
X ₉	Decision making	0.1580 ^{NS}
X ₁₀	Achievement motivation	0.3236**
X ₁₁	Innovativeness	0.5265**
X ₁₂	Scientific orientation	0.4510**
X ₁₃	Risk orientation	0.3475**

* : Significant at 0.05 level of probability

** : Significant at 0.01 level of probability

^{NS} : Non-significant**Table 3. Multiple Linear Regression analysis of the selected independent variables with the managerial role of farm women**

S. No.	Variable	Std. error	'b' values	't' values	'P values'
X ₁	Age	0.0846	0.0413	0.4883 ^{NS}	0.6262
X ₂	Education	0.6772	2.7054	3.9947**	0.0001
X ₃	Farm size	1.3893	-1.5450	-1.1121 ^{NS}	0.2686
X ₄	Family income	0.0206	0.0050	0.2445 ^{NS}	0.8072
X ₅	Extension contact	0.3928	0.6598	1.6796 ^{NS}	0.0959
X ₆	Value orientation	0.4363	1.4822	3.3969**	0.0009
X ₇	Participation	0.2673	0.9401	3.5159**	0.0006
X ₈	Massmedia exposure	0.3845	-0.1187	-0.3088 ^{NS}	0.7580
X ₉	Decision making	0.8467	1.3361	1.5779 ^{NS}	0.1175
X ₁₀	Achievement motivation	0.6021	-0.7798	-1.2951 ^{NS}	0.1980
X ₁₁	Innovativeness	0.3072	0.2871	0.9347 ^{NS}	0.3520
X ₁₂	Scientific orientation	0.4615	1.0054	2.1784*	0.0315
X ₁₃	Risk orientation	0.6167	0.3850	0.6243 ^{NS}	0.5337

Farm women profile characteristics and their managerial role

Majority of the respondents had achievement motivation to some extent as they were better educated, mass media exposure and extension contact and so on. This led to increased managerial role of women farmers in recent times. Individual with high achievement motivation would be determined to reach her goal with concentrated efforts. In this process, she knows the importance of recommended practices and this leads to efficient managerial role of farm women. Hence it is concluded that there was a positive and significant relationship between achievement motivation and managerial role of farm women. The results were in conformity with the findings of Begum (2008).

Innovativeness was associated with the individual's earliness in the adoption of new practice. An innovative farmer always reaps windfall profits from new technologies. Farm women with this trait had better managerial role. Hence there was a positive and significant relationship between innovativeness and managerial role of farm women. The results were in conformity with the findings of Kiran (2000).

Woman farmers with high scientific orientation could prefer to cultivate the crops as per the production recommendations given by the scientists and extension personnel. This gave ample scope for the farm women to think logically and scientifically. Farm women having good scientific orientation will naturally prefer to know advanced technologies in agriculture. Therefore, they are very much interested in knowing about latest agricultural practices. In this process, they might have acquired more knowledge. Hence there was a positive and significant relationship between scientific orientation and managerial role of farm women. This finding was in conformity with the findings of Sreenivasulu and Punnarao (2005).

Risk orientation is expressed as the degree to which a farmer is oriented to take risk. Farm women with this particular trait have a tendency to try new innovations and would naturally prefer to know about advanced technologies and practice them. It is one of the characteristics of innovators and early adopters. Farm women with high risk orientation acquire more knowledge and would have better managerial role. Hence, positive and significant relationship was observed. The results were in line with the findings of Sreenivasulu and Punnarao (2005).

Multiple regression analysis was carried out in order to determine the combined effect of all the independent variables towards variation in dependent variable viz., managerial role of farm women and result was presented in table 3. It could be understood that out of 13 independent variables fitted in regression equation, four independent variables viz., education, value orientation, participation and scientific orientation were found to be positively significant. Coefficient of multiple determination (R^2) was found to be 0.5823 indicating that the above said independent variables could explain variation towards dependent variable viz., managerial role of farm women to the extent of 58.23 per cent. An increase of one unit in education, value orientation, participation and scientific orientation would result in an increase of 3.9947, 3.3969, 3.5159 and 2.1784 units of the managerial role of farm women.

The variables education, value orientation, participation and scientific orientation were positively and significantly contributing to most of the variation in managerial role of farm women. So these variables should be given proper attention while framing any training or developmental programmes intended for improvement of living standards of farm women.

CONCLUSION

It was concluded from the present study that majority of the farm women had medium managerial role. The farm women should have better education, mass media exposure and extension contact and more training should be given to them by the extension agents to improve their managerial role. Adequate extension facilities preferably by female extension workers should also be made available to acquaint them with latest agricultural developments. The transfer of technology to farm women would have to synchronize with the effort in technology generation to reduce drudgery in women life. There is an equal need to conduct research on other profile characteristics of the women farmers for improving their managerial role in agriculture and allied activities.

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CONSTRAINTS FACED BY THE FARMERS IN ADAPTATION TO CLIMATE VARIABILITY AND SUGGESTIONS TO OVERCOME THEM IN KURNOOL DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study determines the constraints faced by the farmers in adaptability measures to climate variability and suggestions expressed by the farmers to overcome the same in Kurnool district of Andhra Pradesh, India. A sample of 120 farmers were selected by random sampling procedure and they were interviewed. The study revealed that a great majority (95.83%) of the farmers perceived price fluctuations in the market, lack of varieties suitable for escaping the terminal drought (94.16%), high incidence of diseases and pests (91.66%) etc. were the major problems. The suggestions to overcome the problems in adaptability to climate variability were in the following rank order; fixing of minimum support price by the government (91.66%), evolving the varieties which can escape the terminal drought in groundnut, cotton and red gram (87.50%).

KEYWORDS: Constraints, climate variability, suggestions

INTRODUCTION

Climate variability refers to the variations in the mean state of the climate and variations in other parameters (such as the occurrence of extremes) on all temporal and spatial scales beyond that of individual weather events. Climate variability is a regular phenomenon every year. Climate variability is more dynamic and adapting to this by the farmers is more challenging. The impact of climate variability is more severely felt in the arid and semi-arid regions where agriculture is mostly dependent on rainfall and ground water.

Kurnool district in Andhra Pradesh is one of the driest districts in the state as monsoons evade this area due to its unfortunate location in a rain shadow region. Being far from the East Coast, it does not enjoy the full benefits of North east monsoon and being cut off by the high Western-Ghats, the South west monsoon often bring little rainfall as well. As a result, the district is deprived of both monsoons and frequently subjected to drought. Keeping this in view, the present study was undertaken to identify the constraints faced by the farmers in adaptation to climate variability and suggestions to overcome them.

MATERIAL AND METHODS

The study was conducted with ex-post-facto research design to assess constraints and suggestions faced by the farmers in adaptation to climate variability in Kurnool district of Andhra Pradesh. Kurnool district was purposively

selected for the study because it is in scarce rainfall zone and very much prone to climate change. One mandal from each of the three revenue divisions of Kurnool district viz., Nandyal, Kurnool and Adoni were selected randomly. Three mandals viz., Banaganapalle mandal from Nandyal revenue division; Orvakallu mandal from Kurnool revenue division and Emmiganuru mandal from Adoni revenue division were randomly selected for the study.

From each of the three selected mandals, two villages were selected for the study viz., Yagantipalle and Yerragudi from Banaganapalle mandal; Ussenapurum and Orvakallu from Orvakallu mandal; Banavasi and Siraladoddi from Emmiganuru mandal. Thus a total of six villages were selected by following random sampling procedure. One hundred and twenty respondents were selected with 20 farmers from each village by following simple random sampling procedure.

RESULTS AND DISCUSSION

Constraints faced by the farmers in adaptation to climate variability

The constraints as expressed by the respondents were tabulated and presented in Table 1.

It is evident from the Table 1 that, price fluctuations in market (95.83%) was the major constraint faced by majority of the farmers.

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Table 1. Constraints faced by the farmers in adaptation to climate variability

S. No.	Constraints	Frequency	Percentage	Rank
1	Price fluctuations in the market	115	95.83	I
2	Lack of varieties suitable for escaping the terminal drought	113	94.16	II
3	High incidence of diseases and pests	110	91.66	III
4	Insufficient training on climate variability coping mechanisms	109	90.83	IV
5	Lack of effective advisory system on changes in climate	108	90.00	V
6	Requirement of money ahead of season for preparedness	105	87.50	VI
7	Frequent interruption in power supply	102	85.00	VII
8	Lack of awareness on pest and disease tolerant varieties	100	83.33	VIII
9	Lack of information pertaining to adaptation options to face the climate variability	98	81.66	IX
10	Higher cost of cultivation using scientific methods	95	79.16	X
11	Absence of suitable rain water harvesting structures	92	76.66	XI
12	Lack of drought mitigating techniques	90	75.00	XII
13	Non availability of credit and subsidy facilities in the locality	88	73.33	XIII
14	Lack of information about weather and climate	82	68.33	XIV
15	Decline in ground water table	82	68.33	XIV
16	Lack of efficient marketing facilities at village level	81	67.50	XV
17	Lack of group action to follow the biological control measures	80	66.66	XVI
18	Adaptation practices requires more labour and time	80	66.66	XVI
19	Lack of proper storage facilities	78	65.00	XVII
20	Repetitive occurrence of extreme weather conditions	78	65.00	XVII

Table 2. Suggestions elicited by the farmers on climate variability

S. No.	Suggestions	Frequency	Percentage	Rank
1.	Fixing of minimum support price by the government	110	91.66	I
2.	Evolving the varieties which can escape the terminal drought in groundnut, red gram and cotton and resistant to pest and diseases	105	87.50	II
3.	Creation of more awareness among farming community on availability of varieties tolerant to pest and diseases.	102	85.00	III
4.	Training to farmers and extension officials on techniques of crop production and adaptation options to address various issues in climate variability	100	83.33	IV
5.	Arrangement for availability of credit and subsidy by the government	98	81.66	V
6.	Contingency plans to minimize the effect of drought should be developed	96	80.00	VI
7.	Weather and climate information should be made available up to farmer's village level	95	79.16	VII
8.	Provision of an effective advisory system and to counsel the farmers on various issues pertaining to the climate variability and measures to overcome.	93	77.50	VIII
9.	Seven hours of continuous and uninterrupted power may be supplied to irrigate of crop for better crop production	90	75.00	IX
10.	Extension officials should consider polambadi programme as a platform to enlighten the farmers on the importance of controlling the pests and diseases	88	73.33	X
11.	The establishment of rainwater harvesting structures at individual farm may enhance the water table in the ground	85	70.83	XI
12.	The officials of department of agriculture should gear up the efforts to disseminate available practices among the farming community which can enhance their capacity to withstand the aberrations in climate	80	66.66	XII
13.	Government should ensure public ware housing facilities in the vicinity of farmers villages	79	65.83	XIII
14.	Contingency plans may be designed with various kinds of models of cropping pattern and cropping system to address repetitive extreme weather conditions	75	62.50	XIV

Other problems expressed by the farmers were in the following rank order, lack of varieties suitable for escaping the terminal drought (94.16%), high incidence of diseases and pests (91.66%), insufficient training on climate variability coping mechanisms (90.83%), lack of effective advisory system on changes in climate (90.00%), requirement of money ahead of season for preparedness (87.50%).

The other problems were frequent interruption in power supply (85.00%), lack of awareness on pest and disease tolerant varieties (83.33%), lack of information pertaining to adaption options to face the climate variability (81.66%), higher cost of cultivation using scientific methods (79.16%), absence of suitable rain water harvesting structures (76.66%), lack of drought mitigating techniques (75.00%), non-availability of credit and subsidy facilities in the locality (73.33%), lack of information about weather and climate (68.33%), decline in ground water table (68.33%), lack of efficient marketing facilities at village level (67.50%), adaptation practices requires more labour and time (66.66%), lack of group action to follow the biological control measures (66.66%), lack of proper storage (65.00%) and repetitive occurrence of extreme weather conditions (65.00%). These results were in conformity with the findings of Kharumnuid (2011) and Archana (2012).

Suggestions elicited by the farmers on climate variability

The suggestions to overcome the problems in adapting to climate variability encountered by the farmers in cultivation of crops were presented in Table 2.

Majority (91.66%) of the farmers suggested fixing of minimum support price by the government, evolving the varieties which can escape the terminal drought in groundnut, red gram and cotton and resistant to pest and diseases (87.50%), creation of more awareness among the farming community on availability of varieties tolerant to pest and diseases (85.00%), training to farmers and extension officials on techniques of crop production and adaptation options to address various issues in climate variability (83.33%). Arrangement for availability of credit and subsidy by the government (81.66%), contingency plans to minimize the effect of drought should be developed (80.00%), weather and climate information should be made available up to farmer's village level

(79.16%), provision of an effective advisory system and to counsel the farmers on various issues pertaining to the climate variability and measures to overcome (77.50%), seven hours of continuous and uninterrupted power may be supplied to irrigate of crop for better crop production (75.00%), extension officials should consider Polambadi programme as a platform to enlighten the farmers on the importance of controlling the pest and diseases (73.33%), establishment of rainwater harvesting structures at individual farm may enhance the water table in the ground (70.83%), the officials of department of agriculture should gear up the effort to disseminate available practices among the farming community which can enhance their capacity to withstand the aberrations in climate (66.66%), government should ensure public ware housing facilities in the vicinity of farmers villages (65.83%), contingency plans may be designed with various kinds of models of cropping pattern and cropping system to address repetitive extreme weather conditions (62.50%).

CONCLUSION

Changes in the mean and the variability of climate parameters will have essential influence on agricultural cropping system especially under water limited production such as in the arid and semi-arid regions. Farmers practice different adaptability measures over the period to mitigate the effect of climate change in the farming.

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EFFECT OF IRRIGATION WATER SOURCES ON MICRONUTRIENTS AVAILABILITY IN A TYPICAL BLACK SOIL OF NORTHERN KARNATAKA

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ABSTRACT

Micronutrient availability is very sensitive to changes in soil environment as influenced by water and nutrient management practices. Surface soil samples representing, areas irrigated with different water sources were analysed for DTPA extractable micronutrients, pH and free CaCO₃. DTPA-extractable micronutrients varied significantly among soils with different irrigation sources. All the micronutrients indicated negative correlations with soil pH and CaCO₃ content but the free CaCO₃ and soil pH showed positive relationship among themselves. The soil micronutrients were found to be significantly higher in stream (lift) water irrigated soils followed by borewell water irrigated soils. However, the least availability was observed in soils with no irrigations. Frequent irrigations for sugarcane in stream irrigated areas resulted in loss of CaCO₃ and reduction in soil pH, which might have contributed for higher micronutrient availability.

KEYWORDS: Black soil, Borewell irrigation, Dryland, Irrigation sources, Soil Micronutrients

INTRODUCTION

Use of water for protective / regular irrigation is essential to achieve Indian Food Security. However, the productivity depends on soil and water quality. To a greater extent, the soil properties, more so the nutrient availability, are influenced by irrigation water. The availability of micronutrients is very sensitive to changes in soil environment especially pH and free CaCO₃ contents as influenced by irrigation water. These soil properties are directly influenced by native soil properties, crop management practices and irrigation sources. This study was conducted systematically for a Taluka (Block) to assess micronutrients availability in a black soil of northern Karnataka influenced by irrigation sources and certain soil properties.

MATERIAL AND METHODS

The study was conducted in black soils of Mudhol taluka / Block (Bagalkot Dist.) during 2014-15. A significant portion of Mudhol taluka was under sugarcane, irrigated with different water sources. The canal irrigation was recorded in areas where canal network system was present. The farmers of tail end portion used bore well water in lean period (Canal + Bore well water). Some of the farmers were found using only groundwater for irrigating sugarcane and other crops (Borewell water).

Water accumulated in streams drained from agricultural lands along the natural drain line was also used through lift irrigation (Lift/Stream water). In some areas, dryland agriculture was practiced without any irrigation facilities (No irrigation). Thus, the study area categorized into canal + borewell, Borewell, Stream, Stream + Borewell and no irrigation systems.

The entire study area was divided into smaller grids of 5.06 sq. km (2.25 × 2.25 km²) and each grid was considered as a sampling unit. The dominant irrigation sources of each grid were identified and a representative composite soil samples were collected. The exact soil sampling points were determined and marked on the toposheet by traversing through each of these sub-units and the sampling points were identified. Three surface soil samples (0-15 cm) were collected and made into one representative composite sample of that site. The soil samples were air dried, sieved (2 mm) and stored for further analysis.

Processed soil samples were analysed for soil reaction (1:2.5) by pH meter (Model Systronics 361), free CaCO₃ content by acid titration (Richards, 1954) and DTPA extractable micronutrients viz. Fe, Mn, Zn and Cu by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Finally, these observations were subjected to suitable statistical tests for interpretations.

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Table 1. Effect of different irrigation water sources on DTPA-extractable iron and manganese contents (in ppm)

Irrigation Water Sources	No. of samples with Fe			Range	Mean \pm SD
	< 2.5	2.5 - 4.5	> 4.5		
Stream Irrigation (Lift)	(n = 22)	0	22 (15.38)	4.54 to 8.80	6.39 \pm 1.27 ^a
Stream + Bore well Irrigation	(n = 6)	0	1 (0.69)	3.42 to 7.58	5.75 \pm 1.60 ^b
Borewell Irrigation	(n = 89)	0	31 (21.67)	2.52 to 8.52	5.18 \pm 1.43 ^{bc}
Canal + Borewell Irrigation	(n = 10)	0	0 (6.99)	4.64 to 8.36	5.77 \pm 1.16 ^{ab}
No irrigation (Dry land)	(n = 16)	0	6 (4.19)	3.27 to 7.38	4.96 \pm 1.07 ^c
Total	(n=143)	0	38 (26.57)		
Statistical analysis Calculated F-value = 4.14; CD at 5% = 0.63					
Irrigation Water Sources	No. of samples with Mn			Range	Mean \pm SD
	< 2.0	2.0 - 4.0	> 4.0		
Stream Irrigation (Lift)	(n = 22)	0	22 (15.38)	4.20 to 15.20	9.06 \pm 2.72 ^a
Stream + Borewell Irrigation	(n = 6)	0	6 (4.19)	4.02 to 13.86	8.32 \pm 3.65 ^{ab}
Borewell Irrigation	(n = 89)	0	3 (2.09)	2.24 to 17.42	9.09 \pm 3.29 ^a
Canal + Borewell Irrigation	(n = 10)	0	0 (6.99)	4.46 to 13.84	7.59 \pm 2.99 ^b
No irrigation (Dry land)	(n = 16)	0	3 (2.09)	2.71 to 11.90	5.73 \pm 2.69 ^c
Total	(n=143)	0	6 (4.19)		
Statistical analysis Calculated F-value = 4.25; CD at 5% = 1.31					

Note: 1. Values in parenthesis depict per cent; 2. Different letters in mean column imply significant differences at $P < 0.05$

Table 2. Effect of different irrigation water sources on DTPA-extractable copper and zinc contents (in ppm)

Irrigation Water Sources	No. of samples with Cu			Range	Mean \pm SD
	< 0.8	0.8 – 1.6	> 1.6		
Stream Irrigation (Lift)	(n = 22)	0	22 (15.38)	2.07 to 5.08	3.48 \pm 0.79 ^a
Stream + Borewell Irrigation	(n = 6)	0	6 (4.19)	2.50 to 4.48	3.63 \pm 0.76 ^a
Borewell Irrigation	(n = 89)	8 (5.59)	81 (56.64)	1.20 to 7.21	2.87 \pm 0.99 ^b
Canal + Borewell Irrigation	(n = 10)	2 (1.39)	8 (5.59)	1.33 to 3.70	2.56 \pm 0.76 ^b
No irrigation (Dry land)	(n = 16)	9 (6.29)	7 (4.89)	0.80 to 4.02	1.70 \pm 0.92 ^c
Total	(n=143)	0	19 (13.28)	124 (86.71)	
Statistical analysis Calculated F-value = 9.83; CD at 5% = 0.38					
Irrigation Water Sources	No. of samples with Zn			Range	Mean \pm SD
	< 0.6	0.6 - 1.5	> 1.5		
Stream Irrigation (Lift)	(n = 22)	0	12 (8.39)	0.75 to 4.38	1.68 \pm 0.89 ^b
Stream + Borewell Irrigation	(n = 6)	0	1 (0.69)	1.20 to 5.61	2.67 \pm 1.60 ^a
Borewell Irrigation	(n = 89)	8 (5.59)	55 (38.45)	0.11 to 5.54	1.37 \pm 0.97 ^{bc}
Canal + Borewell Irrigation	(n = 10)	1 (0.69)	7 (4.89)	0.50 to 2.80	1.10 \pm 0.68 ^c
No irrigation (Dry land)	(n = 16)	9 (6.29)	6 (4.19)	0.11 to 1.59	0.62 \pm 0.33 ^d
Total	(n=143)	18 (12.58)	81 (56.64)	44 (30.76)	
Statistical analysis Calculated F-value = 6.40; CD at 5% = 0.38					

Note: 1. Values in parenthesis depict per cent; 2. Different letters in mean column imply significant differences at $P < 0.05$

RESULTS AND DISCUSSION

DTPA –Fe, Mn, Zn, and Cu

DTPA-Fe in soils ranged from 2.52 to 8.80 ppm (Table 1) and in terms of distribution of available - Fe, nearly $\frac{3}{4}$ th of samples (73.42 %) were found in high range (> 4.5 ppm) while 26.57 per cent samples recorded medium levels(2.5 - 4.5 ppm). Among different irrigation sources, stream irrigated soils had significantly higher amounts of DTPA-Fe with a mean value of 6.39 ± 1.27 ppm and it was on par with canal +borewell irrigated soils (5.77 ± 1.16 ppm). However, dryland (no irrigation) areas recorded lower values of DTPA-Fe (5.18 ± 1.43 ppm).

DTPA-Mn ranged from 2.24 to 17.42 ppm and both of them were observed in borewell irrigated soils. Most of the soil samples (n=137; 95.80%) were found in high range of DTPA- Mn(> 4.00 ppm) while only 4.19 per cent of samples (n=6) were found to be in medium range (2.0-4.0 ppm). Comparison of DTPA-Mn in soils among different irrigation sources revealed that the soils under all irrigation systems were significantly different from each other. Borewell irrigated soils recorded significantly higher available manganese (DTPA- Mn) and the lowest was recorded in dryland areas (5.73 ± 2.69 ppm).

The DTPA-Zn and Cu in soils of different (Table 2) land use categories are ranged from 0.11 to 5.61 ppm. More than half of the soils (56.64%) were medium in DTPA-Zn, while, 30.76 per cent of samples (n=44) were found in high DTPA-Zn (> 1.5 ppm) and only 12.58 per cent of samples (n=18) registered low DTPA-Zn (<0.6 ppm). In terms of irrigation sources, DTPA-Zn content was significantly higher instream + borewell irrigation (2.67 ± 1.60 ppm) and dryland areas recorded significantly lower DTPA-Zn (0.62 ± 0.33 ppm).

The DTPA-Cu in black soils of Mudhol taluka ranged from 0.80 to 7.21 ppm. Among 143 soil samples analysed, most of the soil samples (n=124) showed high levels of DTPA-Cu(>1.6 ppm) and 13.28 per cent of samples (n=19) were in medium range (0.8-1.6 ppm). Among different irrigation sources, soils from stream + borewell irrigated soils recorded highest DTPA-Cu (3.63 ± 0.76 ppm) followed by stream irrigation (3.48 ± 0.79 ppm) and no significant differences were observed between them. However, dryland (no irrigation) areas recorded significantly lower amounts of DTPA-Cu (1.70 ± 0.92 ppm).

Table 3. Correlation coefficients of DTPA – micronutrients with pH and CaCO₃

Parameters	pH	CaCO ₃
DTPA-Fe	-0.190*	-0.260**
DTPA-Mn	-0.168*	-0.194*
DTPA-Zn	-0.177*	-0.198**
DTPA-Cu	-0.181*	-0.334**

*: Significance at 5% level; **: Significance at 5% level

The variations in micronutrient availability among different irrigation sources may be attributed to the direct effects of pH and CaCO₃ on solubility and precipitation reactions (Lindsay, 1972). The soil minerals tend to stay in respective hydroxides at higher pH and thus, the release of nutrients through solubilisation decreases (Pulakeshi *et al.*, 2012). Varied amounts of CaCO₃ in soils also might have altered soil pH and hence, micronutrient availability. The positive relationship between soil pH and CaCO₃ contents (Fig. 1) confirms its negative effect on micronutrient availability. Similar results on reduced micronutrient availability in lime enriched alkaline soils of Madhya Pradesh have been reported by Chouhan *et al.* (2012).

The alkaline pH in these black soils may be attributed to higher free CaCO₃ contents as they are mostly derived from lime parent material (Doddamani, 1994). Occurrence of different sized lime crystals in these soils also indicates CaCO₃ precipitation. However, the amounts of CaCO₃ in soils varied with sources of irrigation water (Fig. 2). Higher amounts of CaCO₃ and alkalinity in soils of dryland and borewell irrigated areas could be attributed to alternate wetting and drying cycles associated with addition of higher amounts of carbonates and bicarbonates through borewell water (Kanwar and Kanwar, 1968). The amounts of free CaCO₃ was found significantly lesser in stream and canal irrigated areas as compared to drylands. This could be attributed to gradual removal of total CaCO₃ by irrigation water. The carbonic acids produced by the dissolution of CO₂ in irrigation water might have reduced total CaCO₃ content in irrigated soils.

CONCLUSION

The DTPA extractal micronutrients in black soils are very sensitive to changes in soil caused by nutrient and water management practices in a cropping systems. The study also revealed that pH and free CaCO₃ contents

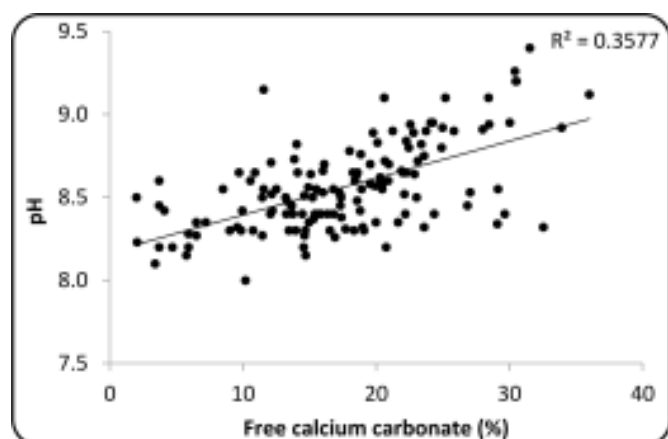


Fig. 1. Relationship between soil pH and free Calcium carbonate (CaCO₃ in %)

varied differently with source of irrigation water and are negatively correlated with availability of DTPA extractable Fe, Mn, Zn and Cu.

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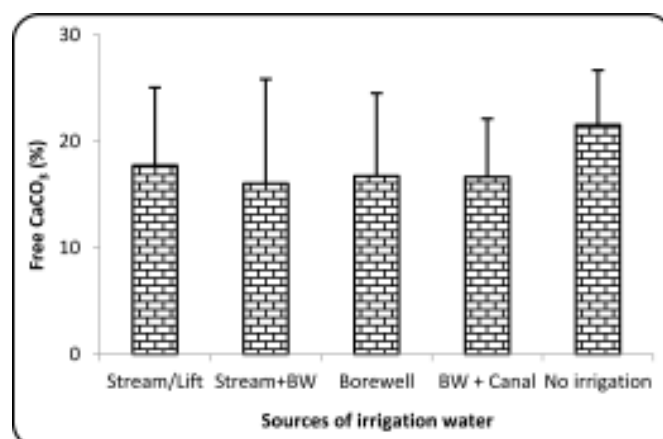


Fig. 2. Distribution of free CaCO₃ in soils irrigated with different water sources

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EFFECT OF SPACING AND SEED SOAKING WITH GA₃ ON GROWTH, YIELD AND QUALITY OF RADISH (*Raphanus sativus* L.)

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ABSTRACT

An the experiment was conducted during Rabi 2009-10 at Akola to study the effect of spacing and seed soaking with GA₃ on growth, yield and quality of radish (*Raphanus sativus* L.). The results revealed that, the significantly the highest plant height (38.20 cm), length of root (25.53 cm), root yield plot⁻¹ (11.30 kg), hectare⁻¹ (261.54 q), ascorbic acid content (16.11 mg/100 g) and minimum pithiness (9.60 %) was recorded in closer spacing of 45 cm x 10 cm (S₁). The wider spacing has significantly superior performance in number of leaves (13.86), Leaf area (161.56 cm²), Fresh weight of leaves (115.20 g), Fresh weight of roots (133.10 g), diameter of the root (3.88 cm) and chlorophyll content (0.61 mg/100 g). The effect of seed soaking with GA₃ was statistically significant at all stages but the treatment G₅ i.e. GA₃ at 40 ppm showed superior performance in all growth, yield and quality parameters in radish.

KEYWORDS: Radish, GA₃, Spacing, Seed soaking

INTRODUCTION

Radish (*Raphanus sativus* L.) belongs to the genus *Raphanus* of the family Cruciferae, it is grown for its young tuberous roots which are eaten raw as a salad or cooked as a vegetable and an appetizer. In India, with increase in population and improvement in dietary habits, the consumption of vegetables has improved. People realize the importance of vegetables in their diet as vegetables have high nutritive value, which are vital for the body. In present scenario, the cultivable land is decreasing continuously due to rapid urbanization, industrialization and shrinking land holdings. In order to fulfil the demand of the people for the improved quality radish, it is essential to increase the production of radish considerably. This can be achieved by bringing more area under cultivation and increasing the productivity. Among the cultural practices plant population had a profound influence on the yield and quality of radish. Plant population also affect the plant growth, development and yield. So, there is every need to find out the optimum plant population Treatment of seed with plant growth regulators is one of the most popular and cheapest methods and has been claimed as an effective tool for improving yield in many crops. Among these plant growth regulators GA is known to have root elongation and enhancement of quality on root crops. Hence, the present investigation was helpful to know the effect of spacing and seed soaking with GA₃ on growth, yield and quality of radish.

MATERIAL AND METHODS

The present investigation entitled, "Effect of spacing and seed soaking with GA₃ on growth, yield and quality of radish" was carried out during Rabi 2009-10. The experiment was laid out with cv. Pusa chetki in Factorial Randomized Block Design with three different spacings i.e. S₁ - 45 cm x 10 cm, S₂ - 45 cm x 15 cm and S₃ - 45 cm x 20 cm and five different concentrations of GA₃ seed soaking i.e. G₁ - control, G₂ - GA₃ at 10 ppm, G₃ - GA₃ at 20 ppm, G₄ - GA₃ at 30 ppm, G₅ - GA₃ at 40 ppm and replicated thrice with fifteen treatment.

Ascorbic acid content in root was estimated by titrating the sample with 2, 6 dichlorophenol indophenol and calculated as per the formula given below.

$$\text{Ascorbic acid (mg/ 100 g juice)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Volume of sample taken for estimation}} \times 100$$

The chlorophyll content of the leaves was estimated in percentage by the following procedure.

- i) 0.0375 g of leaf sample was accurately weighed on electronic mono pan balance and about 10 ml of DMSO (Dimethyl sulphoxide solution) was added to the leaf sample.

Effect of spacing and GA₃ on radish growth and yield

- ii) The samples were kept within the solution for two hours in autoclaves at 60°C.
- iii) After two hours, all the chlorophyll was extracted in the solution.
- iv) The optical density was calibrated at 645 nm for chlorophyll 'a' and 663 nm for chlorophyll 'b' and at 652 nm for total chlorophyll.
- v) Chlorophyll 'a', chlorophyll 'b' and total chlorophyll were calculated with the help of the formula suggested by Arnon (1949).

$$\text{Total chlorophyll} = \frac{\text{O.D. at 65 nm} \times 100}{34.5} \times \frac{V}{100 \times W}$$

where,

O.D. = Optical density

V = Final volume i.e. 10 ml of DMSO

W = Weight of fresh leaves (g)

Chlorophyll 'a' (mg g⁻¹ fresh weight) = 12.7 (O.D.

$$\text{at 663) - } 2.69 \text{ (O.D. at 645)} \times \frac{V}{100 \times W}$$

Chlorophyll 'b' (mg g⁻¹ fresh weight) = 22.9 (O.D.

$$\text{at 645) - } 4.68 \text{ (O.D. at 663)} \times \frac{V}{100 \times W}$$

Freshly harvested roots were cut into three to four pieces and observations on pithiness were taken and expressed in percentage. The data obtained on various observations, during the course of investigation were statistically analyzed by Factorial Randomized Block Design as suggested by Gomez and Gomez (1984).

RESULT AND DISCUSSION

Effect of spacing and GA₃ treatment on growth parameters

Effect of spacing

The data presented in the table revealed that there was a significant difference among the growth characters under study. The significantly maximum plant height (38.20 cm), length of the root (25.53 cm) was recorded with less spacing i.e. S₁ - 45 cm x 10 cm. This might be due to the insufficient space for spreading and severe competition of plants for light and aeration resulting in more vertical growth in closer spacing as compared to

wider spacing. These findings were in conformity with El-Desuki *et al.* (2005) in radish. Where as the treatment with wider spacing i.e. S₃ - 45 cm × 20 cm showed the significantly maximum no of leaves (13.86), Leaf area (161.56 cm²), Fresh weight of leaves (115.20 g), Fresh weight of roots (133.10 g) and diameter of the root (3.88 cm) which was significantly superior over the rest of the treatments. The same treatment recorded less days for germination (5.73) which was desirable. The maximum no of leaves per plant, leaf area, diameter of the root, maximum fresh weight of leaves and root was recorded by wider spacing as compared to closer spacing as a fact that the plants grow at wider spacing got the advantage of better resources like sunshine, aeration and optimum area for nutrient uptake as compared to plants grow under narrow spacing and these results were in conformity with the results of Warade *et al.* (2002) and Parvez *et al.* (2004).

Effect of GA₃ treatment

The data presented in the table revealed that the treatment G₅ i.e. 40 ppm shows significantly superior over other treatments and it was recorded higher values of all growth parameters i.e. plant height (38.87 cm), length of the root (29.01 cm), maximum no leaves (14.34), Leaf area (199.71 cm²), diameter of the root (4.40 cm), Fresh weight of leaves (118.78 g) and Fresh weight of roots (145.08 g) This might be due to the stem elongation caused by application of GA₃. The GA₃ increases auxin production of apex and accelerate the cell division in cambium or other tissues which results in increase in height of plant, length of the root. Similar results were reported by Mahabir Singh and Rajodia (2001) in radish. The treatment G₅ i.e. 40 ppm shows minimum (5.73) days for germination which was desirable. This is might be due to increasing concentrations of GA₃ accelerate the metabolic activity within the embryo of the seed. Similar results were reported Malhotra and Chaudhari (2001) in radish. The interaction between effect of spacing and seed soaking with GA₃ on all growth parameters was not traceable.

Effect of spacing and GA₃ treatment on yield and quality parameters

Effect of spacing

The data presented in the table 2 revealed that the treatment i.e. S₁ - 45 cm × 10 cm shows significantly superior root yield per plot (11.30 kg) and root yield per hectare (261.54 q) and ascorbic acid content in root (16.11

Table 1. Effect of spacing and GA₃ treatment on growth parameters

Treatments	Days required for germination	Height of plant (cm)	Number of leaves plant ⁻¹	Leaf area (cm ²)	fresh weight of leaves (g)	Fresh weight of root (g)	Length of root (cm)
Spacing							
S ₁	7.33	38.20	12.32	150.88	96.99	117.74	25.53
S ₂	6.87	35.71	13.21	155.91	99.86	124.73	24.10
S ₃	5.73	34.32	13.86	161.56	115.20	133.10	22.35
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CD at 5%	0.52	0.73	0.79	5.96	4.58	4.93	1.17
Seed soaking with GA₃							
G ₁	8.33	33.00	11.88	107.28	88.48	108.62	17.19
G ₂	7.00	34.94	12.88	136.93	96.17	115.77	22.58
G ₃	6.89	36.01	13.20	157.70	103.63	123.60	24.16
G ₄	6.33	37.58	13.34	178.97	112.73	132.89	27.00
G ₅	4.67	38.87	14.34	199.71	118.78	145.08	29.01
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CD at 5%	0.68	0.94	1.02	7.69	5.92	6.37	1.51
Interaction (S x G) spacing x seed soaking with GA₃							
'F' test	NS	NS	NS	NS	NS	NS	NS
CD at 5%	-	-	-	-	-	-	-

Table 2. Effect of spacing and GA₃ treatment on yield and quality parameters

Treatments	Diameter of root (cm)	Root yield per plot (kg)	Root yield per hectare (q)	Ascorbic acid content in root (mg/100 g)	Chlorophyll content in leaves (mg/100g)	Pithiness (%)
Spacing						
S ₁	3.25	11.30	261.54	16.11	0.40	9.60
S ₂	3.46	7.48	173.26	14.86	0.50	12.20
S ₃	3.88	6.39	147.84	13.74	0.61	15.40
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CD at 5%	0.41	0.36	8.30	0.95	0.08	0.72
Seed soaking with GA₃						
G ₁	2.59	7.25	167.79	12.30	0.17	19.67
G ₂	3.32	7.77	179.82	13.62	0.40	11.67
G ₃	3.53	8.29	191.79	15.19	0.51	11.33
G ₄	3.81	8.91	206.24	16.16	0.63	10.33
G ₅	4.40	9.74	225.43	17.24	0.81	9.00
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CD at 5%	0.53	0.46	10.72	1.23	0.10	0.92
Interaction (S x G) spacing x seed soaking with GA₃						
'F' test	NS	NS	NS	NS	NS	NS
CD at 5%	-	-	-	-	-	-

mg/100 g) over other treatments. This is due to higher plant population maintained per unit area leads to maximum root yield. Higher yield at closer spacing was also reported by El-Desuki *et al.* (2005) in radish, Da Silva *et al.* (2008) in carrot. The pithiness percent was less in close spacing (9.60 %) which was desirable. The wider spaced plants showed maximum diameter of roots by availing more resources, the roots went over growth, due to which there was more development of pithiness in wider spaced roots. The wider spacing treatment S₃ i.e. 45 cm × 20 cm was found significantly superior over all other treatments and recorded maximum chlorophyll content (0.61 mg/ 100 g) in leaves.

Effect of GA₃ treatment

The data presented in the Table 2 revealed that the treatment G₅ i.e. 40 ppm shows significantly superior over other treatments and it was recorded maximum for all yield and quality parameters i.e. root yield per plot (9.74 kg), root yield per hectare (225.43 q) ascorbic acid content in root (17.24 mg/100 g) and chlorophyll content (0.81 mg/ 100 g) in leaves. Application of GA₃ was responsible for increased growth, root length, root diameter, fresh weight of root and resulted in total root yield. It increases the photosynthetic activities within the plant which resulted in more production of carbohydrates and other photosynthetic product. Increase in carbohydrates directly influenced root diameter, length and weight and ultimately the good yield.

The greater accumulation of CHO in the plant is necessary in order to facilitate the development of root and increase in yield. These results are supported by the findings of Mahabir Singh and Rajodia (2001) in radish, Mondal and Shukla (2005) in onion.

Significantly minimum pithiness (9.00%) was recorded in treatment G₅ i.e. GA₃ at 40 ppm. Under the influence of higher concentration of GA₃, there was more elongation of growth, more root length and there was less pithiness in higher concentration of GA₃. These results are supported by Parvez *et al.* (2004).: The data in respect of interaction effect of spacing and seed soaking with GA₃ on all yield and quality parameters were non significant.

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WEED DYNAMICS, YIELD AND ECONOMICS OF PEARLMILLET (*Pennisetum glaucum* L.) AS INFLUENCED BY DIFFERENT WEED MANAGEMENT PRACTICES

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ABSTRACT

A field experiment was conducted during *kharif*, 2014 at dryland farm of S. V. Agricultural College, Tirupati to study the effects of integrated weed management on growth and yield of pearl millet. Unweeded check resulted in significantly higher weed count, biomass and grain yield than rest of the treatments. An extent of 46.5 % yield reduction was observed with unweeded check over hand weeding twice at 20 and 40 DAS, which recorded significantly lower weed count, biomass and higher yield over rest of the weed management practices. However, it was comparable with pre-emergence application of atrazine @ 750 g a.i. ha⁻¹ *fb* hand weeding at 30 DAS. Pre-emergence application of oxyflourfen @ 100 g a.i. ha⁻¹ resulted in significantly lower yield due to poor weed control and its phytotoxic effects on the crop. In this investigation, integration of Pre - emergence application of atrazine or oxyflourfen *fb* post-emergence application of ethoxysulfuron @ 37.5 g a.i. ha⁻¹ or chlorimuron-ethyl + metsulfuron-methyl @ 8 g a.i. ha⁻¹ at 2-4 leaf stages of weeds did not have any significant impact on weed control and grain yield in pearl millet.

KEYWORDS: Hand weeding, Grain yield, Phytotoxicity, Pre-emergence weed control

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz.] is an important short duration and drought tolerant dual season cereal crop suitable even under adverse weather conditions. In India, it is cultivated over an area of 7.98 m ha with a production of 9.48 m ha and productivity of 1198 kg ha⁻¹. Weed infestation is considered as one of the major drawback during *kharif* to limit the yield in pearl millet as weeds emerge along with the monsoon rains and cause severe competition for growth resources resulting in yield loss upto 40 % or more (Sharma and Jain, 2003).

Intercultivation and hand weeding being the predominant method of weed control in pearl millet, labour scarcity during the peak period of farm operations has become a major bottle neck for manual weeding or intercultivation. The crux of the problem is accentuated if rainfall prolongs for a longer period, making it difficult for manual weeding. So, chemical weed management alone or in combination with mechanical methods has become indispensable for timely weed control, success of which depends mainly on method and depth of sowing as most of the soil applied herbicides cause phytotoxicity

to the crop due to its small seed size and depth of sowing, particularly in direct sown pearl millet.

MATERIAL AND METHODS

A field experiment was conducted at dryland farm of S. V. Agricultural College, Tirupati during *kharif*, 2014 on sandy loam soils with neutral in soil reaction (pH 7.2), low in organic carbon, available nitrogen and medium in available phosphorous and available potassium *i.e.* 232, 27.3 and 247.6 kg of N, P₂O₅ and K₂O ha⁻¹, respectively. The experiment was laid out in a randomized block design with ten treatments *viz.*, pre-emergence application of atrazine @ 750 g a.i. ha⁻¹ (T₁), pre-emergence application of oxyflourfen 100 g a.i. ha⁻¹ (T₂), pre-emergence application of atrazine @ 750 g a.i. ha⁻¹ *fb* hand weeding at 30 DAS (T₃), pre-emergence application of oxyflourfen @ 100 g a.i. ha⁻¹ *fb* hand weeding at 30 DAS (T₄), pre-emergence application of atrazine *fb* post-emergence application of chlorimuron-ethyl 10% + metsulfuron-methyl 10% @ 8 g a.i. ha⁻¹ (T₅), pre-emergence application of atrazine *fb* post-emergence application of ethoxysulfuron @ 37.5 g a.i. ha⁻¹ (T₆), pre-emergence application of oxyflourfen *fb* post-emergence application of chlorimuron-ethyl 10% + metsulfuron-methyl 10% @

8 g a.i. ha⁻¹ (T₇), pre-emergence application of oxyflourfen *fb* post-emergence application of ethoxysulfuron @ 8 g a.i. ha⁻¹ (T₈), hand weeding twice at 20 and 40 DAS (T₉) and weedy check (T₁₀), replicated thrice. Recommended dose of fertilisers 60kg N, 30kg P₂O₅ and 20 kg K₂O ha⁻¹ was applied. Entire quantity of phosphorous and potassium and half of the nitrogen were applied as basal through single super phosphate and muriate of potash and urea, respectively. Remaining half of nitrogen was applied at 30 DAS. The test hybrid “PHB-306” was sown on 1st July with a spacing of 45 × 10 cm. Atrazine and oxyflourfen were applied as pre-emergence spray one day after sowing of the crop and ethoxysulfuron and chlorimuron-ethyl + metsulfuron-methyl at 2-4 leaf stage of weeds *i.e.* 20 DAS with a spray volume of 500 l of water ha⁻¹. Thinning and gap filling were done at 10 DAS. Hand weedings were carried out in the respective treatments at 20, 30 and 40 DAS. Weed density and dry weight were recorded by placing a quadrant of size 0.5 × 0.5 m randomly at three places in each plot and were subjected to square root transformation. Growth and yield attributes were recorded at different growth stages.

RESULTS AND DISCUSSION

Effects on weed

The major weed flora of the experimental site were *Cyperus rotundus* L. (30.7%), and *Cyperus iria* L. (17.0%) among sedges, *Digitaria sanguinalis* L. (9.8%) and *Echinochloa colona* L. (7.5%) among grasses and *Celosia argentia* L. (5.2%), *Commelina benghalensis* L. (4.8%), *Corchorus acutangulus* L. (4.6%), *Phyllanthus niruri* L. (4.3%), *Cleome viscosa* L. (4.1%) and *Merremia aegyptica* L. (3.7%) among broad leaved weeds density and dry weight of weeds were significantly influenced by different weed management practices in pearl millet (Table 1). All the herbicidal treatments reduced the density and dry weight of weeds significantly compared to weedy check. The lowest density and dry weight of weeds was recorded with hand weeding twice at 20 and 40 DAS, which was comparable to pre-emergence application of atrazine *fb* hand weeding at 30 DAS as pre-emergence application of atrazine might have effectively hindered the germination of weeds, while hand weeding at 30 DAS removed the weeds at later stages of crop growth. Pre-emergence application of oxyflourfen registered higher density and dry weight of all categories of weeds due to phytotoxic effect of oxyflourfen on pearl millet resulted in increased weed density in vacant spaces compared to

pre-emergence application of atrazine. The highest density and dry weight of weeds were associated with weedy check. Among the weed management practices tried, the highest WCE was registered with hand weeding twice, which was however, at par with pre-emergence application of atrazine *fb* hand weeding at 30 DAS.

Effects on crop

All the growth parameters *viz.*, plant height and dry matter production were significantly higher with hand weeding twice at 20 and 40 DAS, which was comparable with pre-emergence application of atrazine *fb* hand weeding at 30 DAS. This might be due to weed free condition for a longer period during the crop ontogeny increasing the availability of growth resources to the crop (Table 2). The results are in line with Ram *et al.* (2005). The treatments involving pre-emergence application of oxyflourfen recorded lower values of the above growth parameters due to the phytotoxic effect of oxyflourfen on pearl millet upto “4”. Similar results were also reported by Das *et al.* (2013).

Hand weeding twice at 20 and 40 DAS recorded the highest yield attributes *i.e.* number of panicles plant⁻¹, number of grains panicle⁻¹, test weight, grain and straw yield of pearl millet, which was comparable with pre-emergence application of atrazine *fb* hand weeding at 30 DAS. Weed free condition effectively increased the translocation of photosynthates from source to sink resulting in better yield attributes and thereby better grain yield. These above two treatments recorded 86.5% and 83.3% higher grain yield over weedy check (Table 2). The treatments associated with pre-emergence application of oxyflourfen resulted in reduced yield attributes and yield in pearl millet. This might be due to lesser weed control and phytotoxic effect on crop reducing the grain and straw yield as a result of poor harnessing of utilization growth resources. Post-emergence application of either ethoxysulfuron or chlorimuron-ethyl + metsulfuron-methyl did not produce any significant increase in grain and straw yield. Weedy check recorded significantly lower grain and straw yield than rest of the weed management practices due to heavy weed infestation resulting in lesser availability of growth resources to the crop. These results were in line with DAS *et al.* (2013). Hand weeding twice at 20 and 40 DAS resulted in the highest gross returns, which was at par with pre-emergence application of atrazine *fb* hand weeding at 30 DAS. However, the latter treatment recorded the highest net returns and benefit-

Table 1. Weed density, dry weight and weed control efficiency at harvest as influenced by different weed management practices in pearl millet

Treatments	Dose (<i>a.i.</i> ha ⁻¹)	Time of application (DAS)	Weed density (No. m ⁻²)				Weed dry weight (g m ⁻²)				WCE (%)
			Grasses	Sedges	BLWs	Total	Grasses	Sedges	BLWs	Total	
T ₁ : Pre-emergence (PE) application of atrazine	750 g	1	21.00 (4.69)	95.66 (9.82)	22.00 (4.79)	138.66 (11.81)	5.14 (2.47)	24.85 (5.07)	5.66 (2.58)	35.52 (6.03)	56.0 (48.4)
T ₂ : PE application of oxyflourfen	100 g	1	39.33 (6.34)	100.33 (10.05)	34.66 (5.97)	174.66 (13.23)	9.71 (3.27)	25.24 (5.12)	8.78 (3.12)	43.73 (6.68)	45.9 (42.6)
T ₃ : T ₁ + HW	750 g	1 + 20	7.66 (2.94)	18.33 (4.39)	7.66 (2.94)	33.66 (5.88)	1.92 (1.71)	4.64 (2.37)	2.08 (1.75)	8.64 (3.10)	89.2 (70.8)
T ₄ : T ₂ + HW	100 g	1 + 20	40.00 (6.39)	88.66 (9.46)	32.66 (5.80)	161.33 (12.74)	9.86 (3.28)	22.13 (4.80)	8.27 (3.04)	40.26 (6.42)	50.1 (45.0)
T ₅ : T ₁ + POE application of chlorimuron-ethyl + metsulfuron-methyl	750 g + 8 g	1 + 20	21.00 (4.69)	95.00 (9.78)	21.66 (4.75)	137.66 (11.76)	5.20 (2.47)	23.96 (4.99)	5.46 (2.54)	34.77 (5.98)	56.9 (49.0)
T ₆ : T ₁ + POE of ethoxysulfuron	750g + 37.5 g	1 + 20	35.00 (5.99)	78.00 (8.88)	20.66 (4.65)	133.66 (11.60)	8.74 (3.12)	19.59 (4.53)	5.36 (2.52)	33.71 (5.89)	58.2 (49.7)
T ₇ : T ₂ + POE application of chlorimuron-ethyl + metsulfuron-methyl	100 g + 8 g	1 + 20	23.33 (4.93)	118.00 (10.89)	34.00 (5.91)	165.66 (12.89)	5.78 (2.60)	29.06 (5.47)	8.56 (3.09)	43.41 (6.66)	46.2 (42.8)
T ₈ : T ₂ + POE application of ethoxysulfuron	100 g + 37.5 g	1 + 20	49.00 (7.05)	81.00 (9.05)	33.33 (5.85)	163.33 (12.81)	11.89 (3.58)	20.33 (4.61)	8.40 (3.06)	40.62 (6.44)	49.7 (44.8)
T ₉ : Hand weeding twice at 20 and 40 DAS	-	20 & 40	7.33 (2.88)	17.33 (4.27)	7.33 (2.88)	32.00 (5.73)	1.84 (1.68)	4.42 (2.32)	2.03 (1.74)	8.29 (3.04)	89.7 (71.3)
Weedy check	-	-	86.66 (9.36)	177.33 (13.33)	71.66 (8.49)	335.66 (18.33)	21.49 (4.74)	41.25 (6.50)	18.1 (4.35)	80.84 (9.04)	-
SEm±	-	-	0.17	0.29	0.16	0.26	0.08	0.10	0.07	0.09	0.85
CD (P=0.05)	-	-	0.53	0.86	0.50	0.80	0.23	0.32	0.21	0.28	2.5

Table 2. Yield attributes, yield and economics of pearl millet as influenced by different weed management practices

Treatments	No. of panicles plant ⁻¹	No. of grains panicle ⁻¹	Test weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
T1 : PE application of atrazine	2.36	907.5	5.92	2289	5097	27789	2.74
T2 : PE application of oxyflourfen	1.96	831.2	5.83	1860	4245	19438	2.20
T3 : T1 + HW at 30 DAS	2.80	927.7	6.10	2936	6158	36115	2.82
T4 : T2 + HW at 30 DAS	2.13	845.2	5.89	2055	4646	19298	1.96
T5 : T1 + POE application of chlorimuron-ethyl + metsulfuron-methyl	2.46	912.3	6.06	2339	5148	27858	2.65
T6 : T1 + POE application of ethoxysulfuron	2.53	915.2	6.08	2398	5244	28399	2.63
T7 : T2 + POE application of chlorimuron ethyl + metsulfuron-methyl	2.00	837.2	5.85	1915	4368	19634	2.15
T8 : T2 + POE application of ethoxysulfuron	2.06	841.5	5.88	2007	4556	20814	2.18
T9 : Hand weeding twice at 20 and 40 DAS	2.81	930.5	6.08	2976	6368	33737	2.46
T10 : Weedy check	1.71	770.5	5.75	1595	3701	15247	1.99
SEm±	0.072	20.28	0.054	77.5	149.5	1350	0.072
CD (P=0.05)	0.21	60.2	0.16	232	447	4042	0.21

Weed dynamics, yield and economics of pearl millet

cost ratio due to its lower cost of cultivation. The treatments with pre-emergence application of oxyflourfen recorded lesser gross, net returns and benefit-cost ratio due to lower yield level and higher cost of cultivation. The lowest gross, net returns and benefit-cost ratio were realized with weedy check due to the lowest yield associated with it.

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YIELD AND ECONOMICS OF DHAINCHA [*Sesbania aculeata* (Wills.) POIR] AS INFLUENCED BY TIME OF SOWING AND PHOSPHORUS FERTILIZATION

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ABSTRACT

A field experiment was conducted during *rabi*, 2013 at dryland Farm of S.V Agricultural College, Tirupati, Andhra Pradesh, to identify the optimum sowing time and dose of phosphorus for seed production in Dhaincha. The highest seed yield of Dhaincha was recorded with crop sown during first fortnight of November, which was significantly superior to that of either second fortnight of October or November sowings, while the lowest seed yield was registered with the crop sown during December first fortnight. Application of 45 kg P₂O₅ ha⁻¹ has recorded the highest seed yield over the other Phosphorus levels tried. With respect to interaction sowing of Dhaincha during first fortnight of November with application of 45 kg P₂O₅ ha⁻¹ has recorded the highest seed yield of Dhaincha, which was significantly superior over the rest of the treatment combinations. The lowest seed yield was recorded with sowing of Dhaincha during first fortnight of December with out application of phosphorus. Dhaincha sown during first fortnight of November, at all the four phosphorous levels recorded the maximum gross returns, net returns and returns per rupee of expenditure over the rest of the sowing dates.

KEYWORDS: Dhaincha, Economics, Phosphorus, Time of sowing, Yield.

INTRODUCTION

India has changed from a reign of food scarcity to food security due to increased fertilizer consumption in the recent past. Per hectare consumption of fertilizer in India has been increased from 95.1 kg ha⁻¹ in 1985 to 125.39 kg ha⁻¹ in 2014 (Ministry of Agriculture and Co-operation, 2014).

The costs of chemical fertilizers are steadily increasing and are no longer available since they are exhaustible. Off late, escalating prices of inorganic fertilizers on one hand and non availability of sufficient quantity of chemical fertilizers particularly at peak requirement of major crops on other hand had forced the farming community to identify alternate sources of nutrients to meet their nutrient requirements. Dhaincha [*Sesbania aculeata* (Wills.) Poir] is the most important crop for green manuring *insitu* in India due to its ease of establishment, succulency, and accumulation of huge biomass within a short period. The availability of seed in the market depends on its multiplication but, the farmers are perplexed regarding the optimum time of sowing, nutrient management particularly the phosphorus. In contingency of the above the present experiment was

carried out to study “Prospects of enhancing the seed yield of Dhaincha [*Sesbania aculeata* (Wills.) Poir] under varied time of sowing and phosphorus fertilization”.

MATERIAL AND METHODS

A field experiment was conducted during *rabi*, 2013 at dryland farm of S.V Agricultural College, Tirupati, Andhra Pradesh, to identify the optimum sowing time and dose of phosphorus for seed production in Dhaincha. The experiment was laidout in Randomized Block Design with factorial concept and replicated thrice. The soil of the experimental field was sandy loam, neutral in reaction, low in organic carbon, available nitrogen and phosphorus and medium in available potassium. The treatments comprised of four times of sowing *viz.*, S₁ - Second fortnight of October, S₂- First fortnight of November, S₃ - Second fortnight of November and S₄ - First fortnight of December and four levels of phosphorus application *viz.*, P₁ - Control, P₂-15 kg P₂O₅ ha⁻¹, P₃-30 kg P₂O₅ ha⁻¹ and P₄- 45 kg P₂O₅ ha⁻¹). Uniform dose of 20 kg N and 30 kg K₂O ha⁻¹ through urea and muriate of potash were applied respectively as basal for all the treatments. Phosphorus was applied as per the treatments in the form of single super phosphate at the time of sowing. The seed yields

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Effect of sowing time and phosphorus fertilization on Dhaincha

from each treatment of the net plot were finally recorded. Gross returns were computed considering the prevailing market price of the output. Net returns were arrived by subtracting the cost of cultivation of respective treatments from gross returns for the corresponding treatments. Returns from rupee of expenditure was calculated by using the formula.

Returns from rupee of expenditure =

$$\frac{\text{Net returns (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

RESULTS AND DISCUSSION

Seed yield

Seed yield of Dhaincha was significantly influenced by time of sowing, phosphorus application and there interaction (Table 1). Seed yield of Dhaincha tend to increase significantly with shifting in sowing from October second fortnight to first fortnight of November and further delay in sowing upto first fortnight of December resulted in significant reduction of the seed yield. The highest seed yield (583 kg ha⁻¹) was recorded with sowing of Dhaincha during first fortnight of November, which was significantly superior to either early or later two sowings. Dhaincha sown during first fortnight of November recorded 39.1, 46.1 and 91 percent higher seed yield over October second fortnight or November and first fortnight of December respectively. Significantly higher seed yield with first fortnight of November over early or delayed sowing dates might be due to partitioning of higher proportion of its total drymatter into the reproductive parts (seed) of the plant. Kumar and Singh (1998) also expressed similar views that higher seed yield with the early sown crop was due to availability of optimum growing conditions which are congenial during the crop. The lower seed yield of Dhaincha recorded during October second fortnight compared to November first fortnight was mainly due to excess rainfall *i.e.* 163 mm of rain received in 9 rainy days immediately after sowing. Excess rainfall during initial stages of the crop growth leading to leaching of nutrients in the light soils, as the present experiment was conducted in the sandy loams. Significantly the lowest seed yield (305 kg ha⁻¹) of Dhaincha was recorded with first fortnight of December. The yield reduction under delayed sowings might be the cumulative effects of lower values of growth and yield components resulted in lower yields. These

results are in general agreement with those of Tawaha and Turk (2001), in fababean who indicated that shorter growing period might resulted in lesser drymatter accumulation and fewer pods and branches plant⁻¹, owing to reduces seed yield.

Seed yield of Dhaincha was significantly influenced by application of graded levels of phosphorus. The highest seed yield (560 kg ha⁻¹) of Dhaincha was recorded with application of 45 kg P₂O₅ ha⁻¹, with a significant disparity between any two of the four levels of phosphorus tried. The seed yield of Dhaincha was increased by 14.1, 19.8 and 25.3 percent with application of 15, 30 and 45 kg P₂O₅ ha⁻¹ over control, 15 kg P₂O₅ and 30 kg P₂O₅ ha⁻¹. This might be due to increased availability of P in during the early stages of the plant growth. Phosphorus increases the carboxylation efficiency and stimulated the ribulose-1, 5-diphosphate corboxylase activity, which in turn resulted in increased photosynthetic rate and thereby owing to higher values of yield attributes *viz.*, pods plant⁻¹, seeds pod⁻¹, hundred seed weight and these parameters enhanced the seed yield (Jacob and Lawlor, 1992). Poor available phosphorus (24 kg P₂O₅ ha⁻¹) status of the soil might have a favourable response of Dhaincha to applied phosphorus. The results corroborated with the findings of Turk (1997), Turk and Tawaha (2001) in common vetch.

With respect to interaction, sowing of Dhaincha during first fortnight of November with application of 45 kg P₂O₅ ha⁻¹ has recorded the highest seed yield of Dhaincha, which was significantly superior over the rest of the treatment combinations (Table 4.8). Better growth and development of crop in terms of higher growth and yield attributes *viz.*, number of branches plant⁻¹, pods plant⁻¹, seeds pod⁻¹ and hundred seed weight could have reflected in higher seed yield. The lowest seed yield was recorded with sowing of Dhaincha during first fortnight of December with application 0 kg P₂O₅ ha⁻¹ (S₄ P₁). Lower seed yield with delayed sowing could also be attributed to the shorter growing period with reduced grain growth duration and non availability of phosphorus, as the available phosphorus present in the experimental field is low (24 kg P₂O₅ ha⁻¹), which may not be sufficient to meet the crop demand. Similar results were reported by Yaragoppa *et al.* (2003) and Ulemale and Shivankar (2003) in different green manure crops.

Economics

Economics is the main bone of contention in making the sound recommendations for adoption of any package

Table 1. Effect of sowing time and phosphorus levels on seed yield (kg ha⁻¹) of Dhaincha**Table 2. Gross returns (Rs. ha⁻¹), net returns (Rs. ha⁻¹) and returns per rupee of expenditure of Dhaincha cultivation as influenced by time of sowing of and phosphorus levels**

Treatments	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	Returns per rupee of expenditure
S ₁ P ₁	14805	7339	0.98
S ₁ P ₂	15705	7526	0.92
S ₁ P ₃	20880	11989	1.35
S ₁ P ₄	24075	14471	1.51
S ₂ P ₁	20565	13099	1.75
S ₂ P ₂	22860	14681	1.79
S ₂ P ₃	27765	18874	2.12
S ₂ P ₄	33795	24191	2.52
S ₃ P ₁	14355	6889	0.92
S ₃ P ₂	16650	8471	1.04
S ₃ P ₃	18360	9469	1.07
S ₃ P ₄	22410	12806	1.33
S ₄ P ₁	9180	1714	0.23
S ₄ P ₂	11925	3746	0.46
S ₄ P ₃	13410	4519	0.51
S ₄ P ₄	20475	10871	1.13

Note: Sale price of Dhaincha seed: Rs. 45 kg⁻¹

Effect of sowing time and phosphorus fertilization on Dhaincha

of practices by farmers. Gross and net returns as well as returns per rupee expenditure were altered to a noticeable extent by time of sowing and phosphorus application (Table 3.). Maximum gross returns were realized with sowing of Dhaincha during the first fortnight of November with application of phosphorus @ 45 kg P₂O₅ ha⁻¹ (Rs. 33795 ha⁻¹) followed by first fortnight of November sowing with application of phosphorus @ 30 kg P₂O₅ ha⁻¹ (27765 Rs. ha⁻¹). The same trend was reflected in net return and returns per rupee of expenditure. First fortnight of November contributed to higher seed yield which in turn increased the gross and net returns as well as returns per rupee of expenditure due to increased seed yield. Kumar *et al.* (2005) reported the maximum gross returns, net returns and returns per rupee expenditure with early sowing in sunhemp. Increased benefits of Dhaincha seed crop as regards to gross returns and returns per rupee investment with early sowing were also reported by Kumar *et al.* (2006). Rest of the treatment combinations performed far below returns compared to above treatment combinations. December first fortnight sowing has recorded very low net returns due to lesser seed yield and higher cost of cultivation. These results are in conformity with those of Ulemale and Shivankar (2003) in sunhemp. Dhaincha sown during first fortnight of November, at all the four phosphorous levels recorded the maximum gross returns, net returns and returns per rupee of expenditure over the rest of the sowing dates.

CONCLUSION

It can be concluded that sowing of Dhaincha during first fortnight of November with application of 45 kg P₂O₅ ha⁻¹ has resulted in higher seed, stalk yield and harvest index with maximum gross returns, net returns and returns per rupee of expenditure during *rabi* in the Southern Agro Climatic Zone of Andhra Pradesh.

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PRODUCTION POTENTIAL AND ECONOMICS OF MAIZE (*Zea mays* L.) AS INFLUENCED BY DIFFERENT NUTRIENT LEVELS UNDER ZERO TILLED CONDITION IN RICE – MAIZE CROPPING SEQUENCE

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ABSTRACT

Field experiments were conducted on sandy clay loam soils of Agricultural College Farm, Bapatla during 2008-2009 and 2009-2010 to study the production potential and economics of maize as influenced by different levels of nitrogen, phosphorus applied to *kharif* rice and fertilizer schedules given to maize during *rabi* under zero tilled condition. The treatments consisted of four nitrogen levels i.e. green manuring @5 t ha⁻¹, 80 kg N ha⁻¹, 120 kg N ha⁻¹, 240 kg N ha⁻¹, three phosphorus levels i.e. 0, 30 and 60 kg P₂O₅ ha⁻¹ to preceding rice and three fertilizer schedules i.e. 0, 50 and 100% recommended dose of fertilizers (RDF) to succeeding maize. Application of 240 kg N ha⁻¹ in combination with 60 kg P₂O₅ ha⁻¹ to preceding rice and 100% RDF to maize significantly increased the yield attributes, grain yield, straw yield and monetary returns of maize over other levels of nitrogen, phosphorus applied to rice during *kharif* and fertilizer schedules given to zero tilled maize during *rabi* season.

KEYWORDS: Rice–maize, grain yield, straw yield, economics and zero tillage.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal grain crop next to rice and wheat and has highest production potential among the cereals. It is cultivated in India over 8.71 million ha with 22.06 million tonnes production having an average productivity of 2556 kg ha⁻¹ and contributing to nearly 8 per cent in the national food basket (ASG, 2014). In Andhra Pradesh, maize is cultivated in an area of 1.2 lakh. ha with a production of 4.97 lakh. tonnes with an average yield of 4673 kg ha⁻¹ (ASG, 2014).

In recent years, rice - maize sequence has gained importance in place of rice - blackgram sequence in the Krishna and Godavari agro-climatic zones of Andhra Pradesh due to late release of canal water and severe weed and disease problems particularly, seven yellow vein mosaic virus incidence in rice - fallow blackgram. Rice fallow maize under zero-tillage is being practiced by grain, dairy, poultry, and vegetable farmers and accepted as a beneficial cropping system with large and small operations. Growers adopt this system to increase their efficiency and profitability, and to improve their environmental stewardship. Keeping this in view, the present investigation was carried out to know the suitable

fertilizer schedule to improve the yield attributes, yield as well as economics and also to know the residual effect of different levels of nutrients on the performance of maize in rice based cropping sequence under zero tilled conditions.

MATERIAL AND METHODS

Field experiments were conducted on maize (*Zea mays* L.) in rice based maize cropping system during 2008-2009 and 2009-2010 at Agricultural College Farm, Bapatla with three fertilizer schedules i.e. 0, 50 and 100% recommended dose of fertilizers (RDF) to *rabi* maize and four levels of nitrogen i.e. 80 kg N ha⁻¹, 120 kg N ha⁻¹, 240 kg N ha⁻¹, green manuring @5 t ha⁻¹, three levels of phosphorus i.e. 0, 30 and 60 kg P₂O₅ ha⁻¹ given to preceding *kharif* rice. The experiment was carried out in randomized block design with factorial concept and replicated thrice. Maize hybrid 30 V 92 was used for the study. The experimental soil was sandy clay loam having a pH of 8.2, low in available nitrogen (176 kg ha⁻¹), and high in phosphorus (39 kg ha⁻¹) in available potassium (551 kg ha⁻¹). A total rainfall of 37.6 mm and 2.01 mm was received during growing period of the seasons in 2008-09 and 2009-10 respectively. The data were collected on five randomly selected plants in each plot in

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each season and the data are subjected for statistically analysis.

RESULTS AND DISCUSSION

YIELD ATTRIBUTES

The yield attributes (Table. 1 and 2) such as cobs per plant, cob length, grains per cob and test weight significantly influenced by levels of nitrogen and phosphorus applied to *kharif* rice and fertilizer schedules applied to maize crop during *rabi* season.

All the yield attributes increased significantly with increase in the level of nitrogen application from 80 to 240 kg N ha⁻¹, but the green manure incorporation recorded significantly higher yield attributes over 80 kg N ha⁻¹ treatment except number of grains per cob (between N₈₀ and N₁₂₀) and test weight (between N₈₀ and N₁₂₀) during both the years of the study. With each increment in phosphorus application significantly increased all yield attributes of maize during both the years of study, except number of grains per cob during first year of study, similarly with each increment in fertilizer schedules from 0 to 100 % recommended dose of fertilizer, there was a progressive and significant increase in all the yield attributes during both the years of the study except number of grains per cob. The increase in yield attributes such as cobs per plant, cob length and test weight might be due to enhancement in growth attributes which lead to photosynthates partitioning and better source –sink relationship due to increased levels of N, P and fertilizer schedules. Kumar *et al.*, (2014) also reported similar findings in maize.

YIELD

The rate of increase in grain yield of succeeding maize crop following application of 240 kg N ha⁻¹ and 120 kg N ha⁻¹ over 80 kg N ha⁻¹ was 61.8 %, 53.6% and 45.1%, 38.1% during 2008-09 and 2009-10 respectively. An increase of 15.3% and 10.1% in grain yield was observed due to green manuring during first and second year of study, respectively. This might be due to the beneficial effect of organic manure, which plays an important role in enhancing efficient utilization of native as well as applied nutrients through matching nutrient availability with the crop demand to exhibit higher crop productivity.

There was a progressive and significant increase in grain yield due to increasing levels of phosphorus from 0 to 60 kg P₂O₅ and fertility schedules from 0 to 100%

recommended dose of fertilizers. The increase in grain yield due to 60 and 30 kg P₂O₅ ha⁻¹ over control was 29.2%, 21.2%, while an increase of 19.1%, 12.4% was observed in grain yield due to application of 100% and 50% RDF over control.

Application of increased levels of nitrogen, phosphorus and fertilizer schedules i.e. 0, 50 and 100% recommended dose of fertilizers brought about significant increase in grain yield in maize during both the years of experimentation. It might be due to the beneficial effect of higher level of nitrogen, phosphorus and fertilizer schedules on growth and development by way of increased yield attributes thus, registering the higher grain yield. The present findings collaborate with the earlier reports of Mahala *et al.*, (2006) and Lingaraju *et al.* (2010). Similarly, the stover yield of maize followed the same trend as that was noticed in respect of grain yield of maize.

ECONOMICS

Gross returns, net returns and rupee return per rupee invested were worked out for different levels of nitrogen, phosphorus for preceding *kharif* rice and fertilizer schedules for maize in rice fallow maize cropping sequence (Table 3).

Among the different nitrogen levels applied to rice during *kharif*, application of 240 kg N ha⁻¹ recorded the maximum gross returns and net returns of Rs. 218820/-, Rs. 196350/- respectively and rupee return per rupee investment of 1.11 during first year and Rs. 218798/-, Rs. 196262/- respectively and 1.11 during the second year. The highest gross returns, net returns and rupee return per rupee invested were the with application of phosphorus @ 60 kg P₂O₅ ha⁻¹. This treatment was closely followed by application of 30 kg P₂O₅ ha⁻¹. Hence, the present investigation revealed that through the application of 240 kg N ha⁻¹ in combination with 60 kg P₂O₅ ha⁻¹ recorded the maximum gross returns, net returns and rupee return per rupee investment, but it was at par with the application of 240 kg N ha⁻¹ in combination with 30 kg P₂O₅ ha⁻¹ for rice crop, which seems to be more economical than that of 240 kg N ha⁻¹ in combination with 60 kg P₂O₅ ha⁻¹. Similar results were reported by Reddy Ramu, (2005).

However, maximum net returns were recorded with 240 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹ and 100% recommended dose of fertilizer during both the years of experimentation in rice fallow maize crop sequence. This might be due to

Table 1. Residual effect of different treatments imposed to *kharif* rice on yield attributes of succeeding maize

Treatments imposed to rice	2008-09					2009-10							
	No. of cobs plant ⁻¹	Cob length (cm)	No. of grains cob ⁻¹	Grain weight cob ⁻¹ (g)	No. of cobs plant ⁻¹	Cob length (cm)	No. of grains cob ⁻¹	Grain weight cob ⁻¹ (g)	No. of cobs plant ⁻¹	Cob length (cm)	No. of grains cob ⁻¹	Grain weight cob ⁻¹ (g)	
GM 5 t ha ⁻¹	1.1	11.2	139.0	27.8	1.3	12.6	157.5	40.0					
N ₈₀	1.2	11.0	134.0	24.4	1.3	12.0	150.5	36.7					
N ₁₂₀	1.4	12.1	142.1	30.6	1.6	13.6	168.4	45.2					
N ₂₄₀	1.6	13.4	151.6	36.7	1.7	15.1	175.4	52.0					
SEm ±	0.02	0.09	2.07	0.43	0.03	0.19	3.00	0.79					
CD (0.05)	0.06	0.3	5.8	1.2	0.08	0.5	8.4	2.2					
			Nitrogen levels (kg ha ⁻¹)										
			Phosphorus levels (kg ha ⁻¹)										
P ₀	1.2	10.8	136.8	25.9	1.4	12.3	155.1	38.0					
P ₃₀	1.3	11.7	141.3	29.5	1.5	13.1	163.1	43.1					
P ₆₀	1.5	13.2	147.0	34.3	1.6	14.5	170.6	49.4					
SEm ±	0.01	0.08	1.8	0.37	0.02	0.17	2.59	0.68					
CD (0.05)	0.05	0.2	5.0	1.0	0.07	0.4	7.3	1.9					
			Fertilizer schedules (RDF) given to maize										
0%	1.2	11.2	138.0	26.7	1.4	12.5	156.0	36.0					
50%	1.4	11.7	141.1	30.0	1.5	13.2	163.0	44.2					
100%	1.6	12.2	146.1	33.0	1.7	14.3	170.0	50.2					
SEm ±	0.01	0.08	1.8	0.37	0.02	0.17	2.59	0.68					
CD (0.05)	0.05	0.2	5.0	1.0	0.07	0.4	7.3	1.9					

Table 2. Residual effect of different treatments imposed to *kharif* rice on test weight, grain yield and stover yield of maize

Treatments imposed to rice	2008-09			2009-10			
	Test weight (g 100 ⁻¹)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Test weight (g 100 ⁻¹)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	
GM 5 t ha ⁻¹	24.0	3384	4116	24.8	3544	4348	
N ₈₀	23.6	2935	3567	24.2	3219	3802	
N ₁₂₀	24.3	4258	5175	25.7	4445	5409	
N ₂₄₀	27.6	4750	5785	27.2	4944	5991	
SEm ±	0.21	107.6	117.4	0.28	92.2	118.0	
CD (0.05)	0.6	303	331	0.8	260	333	
		Nitrogen levels (kg ha ⁻¹)					
P ₀	24.1	3282	3991	24.7	3451	4203	
P ₃₀	24.5	3974	4837	25.5	4168	5071	
P ₆₀	26.0	4240	5155	26.2	4428	5388	
SEm ±	0.18	93.1	101.6	0.24	79.9	102.2	
CD (0.05)	0.5	262	286.8	0.7	225	288	
		Phosphorus levels (kg ha ⁻¹)					
0%	23.5	3441	4185	24.3	3634	4696	
50%	25.0	3892	4737	25.6	4085	4970	
100%	26.4	4159	5062	26.7	4328	5297	
SEm ±	0.18	93.1	101.6	0.24	79.9	102.2	
CD (0.05)	0.5	262	286.8	0.7	225	288	
		Fertilizer schedules (RDF) given to maize					

Table 3. Effect of levels of nitrogen and phosphorus in combination with fertilizer schedules on economics of maize in rice-fallow maize cropping system

Treatments imposed to <i>kharif</i> rice	2008-09			2009-10		
	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	Rupee returned per rupee invested	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	Rupee returned per rupee invested
GM 5 t ha⁻¹						
		Nitrogen levels (kg ha ⁻¹)				
N₈₀	165642	143172	1.15	151806	129270	1.17
N₁₂₀	127610	105140	1.21	127588	105052	1.21
N₂₄₀	194993	172523	1.13	194970	172434	1.13
	218820	196350	1.11	218798	196262	1.11
		Phosphorus levels (kg ha ⁻¹)				
P₀	156341	133872	1.17	145959	123422	1.19
P₃₀	180270	157801	1.15	180248	157712	1.15
P₆₀	193687	171217	1.14	193665	171128	1.14
		Fertilizer schedules (RDF) given to maize				
0%	225391	204809	1.10	204809	184227	1.10
50%	232423	209887	1.10	232422	209886	1.10
100%	248124	223833	1.10	247923	223432	1.10

Effect of nutrient levels on zero tilled rice - maize cropping sequence

application higher levels of nitrogen and phosphorus increased the grain yield there by increased the gross returns and net returns. The present findings collaborate with the findings of Sivalakshmi and Sambasiva Reddy (2006) and Thakur and Vinod Sharma (1999).

The present investigation revealed that application of 240 kg N ha⁻¹ in combination with 60 kg P₂O₅ ha⁻¹ applied to *kharif* rice and 100 % recommended dose of fertilizer given to *rabi* maize resulted in higher grain yield, maximum gross returns and net returns of maize in rice fallow maize cropping sequence during both the years.

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