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Effect of crop geometry, weed management practices and nutrient levels on performance of rainfed sunflower (*Helianthus annuuas* L.)

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ABSTRACT

The present investigation was conducted during *Rabi* season of 2003 and 2004 at Agricultural Research Station, Podalakur (Nellore district) of Andhra Pradesh to find out appropriate crop geometry, optimum nutrient level, efficient weed control method for rainfed sunflower on vertisols. From the investigation it was revealed that sowing of sunflower at a spacing of 60 x 30 cm along with the pre-emergence application of pendimethalin + one intercultivation at 25 DAS and application of 125 per cent recommended dose of nutrients (100 kg N, 62.5 kg P_2O_5 and 37.5 kg K_2O ha^{-1}) was found to be the best package of agro-techniques for rainfed sunflower on vertisols of Southern Agro-climatic zone of Andhra Pradesh, for realizing higher productivity and economic returns.

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Key words : Sunflower, Crop geometry, Weed control methods, Nutrient levels

INTRODUCTION

Dry land agriculture is beset with an array of problems, the paramount of them being the vagories of monsoon, which is most undependable, both in quantity and time and thus it dictates the success or failure of crop production. In Nellore district of Southern Agro-climatic Zone of Andhra Pradesh, Black gram is the principal crop of rained areas during *Rabi* season. Inconsistent and erratic behaviour of North-East monsoon has been resulting in unremunerative productivity of Black gram in this region. To overcome this climatic constraint, several alternate crops *viz.,* redgram, jowar, horse gram, bengal gram, soybean and sunflower were tested and found to be more remunerative compared to black gram. Among the alternate crops tried, sunflower was more promising for this region. Sunflower (*Helianthus annuus*) is a versatile edible oil seed crop having several inherent advantages like wide adaptation to different soil types and seasons, good seed multiplication ratio, photo–insensitivity and yields fine quality of edible oil. Because of these advantages, sunflower is becoming a preferred crop, mostly, under rainfed farming by small and marginal farmers.

In Andhra Pradesh, sunflower is cultivated in 4.9 lakh ha of area with a production of 3.3 lakh tones, the productivity being 679 kg ha^{-1} (Plant doctor's diary, 2005). In the backdrop of the above, there is immense need to enhance the productivity of sunflower, to contribute to the oilseed economy of the country. Such uphill task is undisputedly on the shoulders of agronomists, who have to exploit the potential of modern genotypes by evolving appropriate agrotechniques suitable to the agroclimatic regions.

Growth of the sunflower crop varies with the planting pattern, resulting in variation of the plant stature and canopy coverage. In this context, the arrangement of plants *i.e.*, crop geometry is likely to play an important role, which makes it necessary to find out suitable planting geometry. Similarly, mineral nutrition plays a significant role in influencing the productivity of sunflower, which makes it imperative to identify the optimum dose of nutrients. Added to this, the occurrence of weeds during the early stages of crop growth, a universal phenomenon in rainfed areas, results in huge yield loss of sunflower. Hence, it is essential to find out a proper method of weed control in this crop. In light of the above, the present investigation was planned to find out appropriate crop geometry, optimum nutrient level, efficient weed control method for rainfed sunflower on vertisols of Southern Agro-climatic Zone of Andhra Pradesh.

MATERIALS AND METHODS

The present investigation was conducted during *Rabi* season of 2003 and 2004 at Agricultural Research Station, Podalakur (Nellore district) of Andhra Pradesh. The soil samples were composited for each season separately and analyzed for different physico-chemical properties. The soil was clay in texture, alkaline in reaction (pH 8.4), low in organic carbon (0.27 %) and available nitrogen (163 kg N ha^{-1}), medium in available phosphorus (22. 2 kg P_2O_5

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ha^{-1}) and available potassium (182.4 kg K_2O ha^{-1}). The experiment was laid out in a Split Plot Design and replicated thrice. The treatments consisted of combination of crop geometry (3) x weed control (2) methods as mainplot treatments *viz.*, crop geometry methods G_1 : 45 cm x 40 cm, G_2 : 60 cm x 30 cm, G_3 : 75 cm x 24 cm, weed control methods W_1 : Two inter cultivations at 25 and 45 DAS, W_2 : Pre-emergence application of pendimethalin @ 1.0 Kg a.i ha^{-1} + one intercultivation at 25 DAS and nutrient levels as sub plot treatments *viz.*, F_1 :100% recommended dose of nutrients (80N + 50 P_2O_5 + 30 K_2O kg ha^{-1}), F_2 :125% recommended dose of nutrients (100N + 62.5 P_2O_5 + 37.5 K_2O kg ha^{-1}), F_3 : 150% recommended dose of nutrients (120N + 75P_2O_5 + 45 K_2O kg ha^{-1}). The fertilizers were applied as per the treatments. Half the dose of nitrogen and full dose of phosphorus and potash were applied basally at the time of sowing, while the remaining half of nitrogen was top dressed at 30 DAS during both the years of experimentation. The required quantity of the herbicide pendimethalin was calculated and sprayed as pre-emergence application @ 1.0 kg a.i ha^{-1} on the soil immediately after sowing as per the treatments.

Weather during first year of experiment:

The maximum and minimum temperatures and the relative humidity were almost similar to that of the decennial average for the corresponding years. These parameters were favourable during the crop period (18.10.2003 to 16.01.2004) for growth and development. A rainfall of 386.0 mm was received in 14 rainy days which was lesser by 36 per cent than the decennial average rainfall of 604.7 mm received in 21 rainy days. There was a dryspell during the crop growth period from 16.11.2003 to 15.12.2003 and from 01.01.2004 upto harvest. These drought periods coincided with the bud initiation and flowering stages of the crop.

Weather during second year of experiment:

Weather parameters like maximum and minimum temperature and relative humidity during the crop period (19.10.2004 to 17.01.2005) were favourable for growth and development. A total rainfall of 454.1 mm was received in 16 rainy days which was lesser by 20 per cent than the decennial average of 604.7 mm received in 21 rainy days. There was a prolonged drought period from 14.11.2004 upto harvest which coincided with bud initiation, flowering and grain formation stages of the crop.

RESULTS AND DISCUSSION

The results obtained from the present investigation have been duscussed below:

Response of sunflower to crop geometries and weed management methods:

Growth:

Altered crop geometry, keeping the plant population same, influenced the growth of sunflower. In case of plant height at 40 DAS, crop geometry of 75 x 24 cm along with two intercultivations at 25 and 45 DAS resulted

Table 1 : Growth of sunflower as influenced by crop geometry, weed control methods and nutrient levels (mean of 2 years data)

Treatments	Plant height (cm)				LAI				DMP (kg ha^{-1})				Days to 50% flowering	Days to maturity
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest		
Crop geometry and weed control method														
G_1W_1	24.7	62.3	104.0	125.5	0.25	0.74	1.3	1.14	285	877	1239	2287	51	83
G_1W_2	27.2	64.5	108.1	128.5	0.24	0.75	1.25	1.2	311	894	1471	2262	51	86
G_2W_1	26.3	61.7	109.7	125.4	0.24	0.84	1.31	1.13	312	904	1355	2298	52	85
G_2W_2	25.9	64.1	108.6	130.5	0.24	0.83	1.27	1.2	619	905	1428	2440	52	84
G_3W_1	28.0	64.5	112.2	125.7	0.24	0.84	1.43	1.13	286	921	1380	2357	51	85
G_3W_2	27.8	61.5	110.3	125.4	0.25	0.79	1.24	1.17	286	874	1367	2203	51	85
S.E. $\pm$	0.89	0.83	3.27	2.56	0.006	0.066	0.041	0.025	13.1	19.6	47.2	85.1	0.31	0.45
C.D. (P=0.05)	NS	2.6	NS	NS	0.02	NS	0.13	NS	NS	62	149	268	NS	1.4
Nutrient levels														
N_1	25.5	59.7	103.0	125.16	0.21	0.75	1.28	1.11	276	842	1286	2086	51	85
N_2	27.3	63.9	110.2	126.5	0.25	0.82	1.34	1.19	305	898	1408	2401	52	85
N_3	28.4	65.6	113.4	128.9	0.27	0.83	1.30	1.18	313	929	1411	2426	52	84
S.E. $\pm$	0.44	1.04	1.06	1.06	0.005	0.053	0.022	0.014	10.0	11.8	35.0	60.6	0.28	0.34
CD (P=0.05)	1.3	2.9	3.1	3.1	0.01	NS	0.06	0.04	29	34	102	176	0.8	NS

NS=Non-significant

in maximum plant height but was comparative with the crop geometry of 45 x 40 cm and 60 x 30 cm coupled with pendimethalin + one intercultivation (Table 1). At 60 DAS, except 45 x 40 cm with two intercultivations, all the other treatment combinations were comparable to each other. At harvest also there were no significant differences in treatments. This at par performance by all the treatments might be due to the sufficiency of rainfall received during the crop growth period. However, 60 x 30 cm and 45 x 40 cm with pendimethalin + one intercultivation and crop geometry of 75 x 24 cm with two intercultivations resulted in comparable values of plant height at harvest which might be due to prolonged drought period from 25th day onwards.The shortest plants, at harvest, were obtained with the crop geometry of 45 x 40 cm along with two intercultivations. On the other hand, the plant height recorded by 75 x 24 cm and 60 x 30 cm with two intercultivations was comparable to each other which might be due to the intra-row competition for solar radiation forcing the plants to grow taller (Karami, 1980; Ashoub *et al.,* 1986). In case of leaf area index, the crop geometries of 75 x 24 cm and 60 x 30 cm, either with or without herbicide accounted for relatively higher leaf area indices while the crop geometry of 45 x 40 cm under both the weed control methods resulted in lower leaf area index. The higher leaf area index might be due to the production of more number of larger leaves. These results are in accordance with Shiv Kumar (1973) and Srinivasa and Patil (1975).

Maximum drymatter production at harvest was observed with the crop geometry of 60 x 30 cm along with the pre-emergence application of pendamethalin + one intercultivation at 25 DAS, which was at par with the crop geometry of 75 x 24 cm along with two intercultivations (G_3W_1) but superior to all other treatments. The higher drymatter production might be attributed to relatively better plant growth and leaf area index with large sized leaves, leading to higher photosynthetic area and improved functional activity of leaves through better light interception (Steer *et al.,* 1993; Srinivasa and Patil 1977).

Weed density and weed drymatter:

The total weed density, at all stages of crop growth, was less with all the crop geometries when coupled with pre-emergence application of pendamethalin + one intercultivation (Table 2). The purple nut sedge (*Cyperus rotundus*) alone was the major component in the total weed density counts with pendimethalin + one intercultivation treatment, though significantly lower density of purple nut sedge was registered with these treatments compared to two intercultivations. The total weed population in the treatment combinations involving two intercultivations was higher compared to pendimethalin treated plots which was due to the fact that in case of herbicide treated plots, the total weed control was effective even from early stages due to herbicide application. Effectiveness of pendimethalin on grasses and broad leaved weeds was reported by Poonguzhalan *et al.* (1996).

At all stages of crop, lower drymatter of weeds was recorded with pre-emergence application of pendimethalin

Table 2 : Weed density and weed dry matter as influenced by crop geometry, weed control methods and nutrient levels (mean of 2 years data)

Treatments	Weed density (m^{-2})				Weed drymatter (gm^{-2})			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Crop geometry and weed control method								
G_1W_1	67	45	38	50	16	19	19	29
G_1W_2	23	29	54	64	11	15	31	37
G_2W_1	59	41	39	44	21	20	22	30
G_2W_2	22	28	49	64	12	17	30	45
G_3W_1	71	44	42	54	24	16	25	34
G_3W_2	25	35	49	63	13	15	28	44
S.E. $\pm$	1.7	0.71	0.95	0.41	0.62	0.57	0.4	0.61
C.D. (P=0.05)	5.3	2.2	2.1	1.2	1.9	1.8	1.2	1.9
Nutrient levels								
N_1	41	31	41	50	14	15	25	34
N_2	46	38	46	56	17	17	26	37
N_3	47	41	50	63	18	18	27	39
S.E. $\pm$	0.93	0.61	0.44	0.68	0.32	0.37	0.38	0.54
C.D. (P=0.05)	2.7	1.7	1.2	2.0	0.9	1.1	1.1	1.5

+ one intercultivation compared to two intercultivations. The conjunctive use of herbicides and intercultivation led to efficient early weed control compared to two intercultivations alone. Higher drymatter of weeds was noticed with two intercultivations which was due to the reason that intercultivation effect was seen after physical removal of weeds only compared to early weed control by pre-emergence application of herbicides. These results are in agreement with Suresh (1991), Sanjay Reddy (1993) and Poonguzhalan *et al.* (1996).

Yield attributes, yield and economics:

The crop geometry and weed control methods did not influence the size of the flower head (Table 3). Under both the weed control methods, the higher number of filled seeds were observed with 60 x 30 cm and 45 x 40 cm, whereas, lower number of seeds were observed with 75 x 24 cm. In case of filling percentage, the crop geometry of 60 x 30 cm was found to be superior compared to other crop geometries. This might be due to higher drymatter production and effective partitioning of assimilates, allocating the current as well as reserved assimilates towards yield attributes.

Enhanced seed yield obtained with the crop geometry of 60 x 30 cm along with pre-emergence application of pendimethalin might be ascribed to elevated growth profile which could have led to excellent source-sink relationship leading to improved yield attributing characters ultimately resulting in enhanced seed yield under the crop geometry of 60 x 30 cm (Dev Kumar and Mohammad, 2001; Patel and Thakur, 2003).

Crop geometry of 60 x 30 cm with pre-emergence application of pendimethalin + one intercultivation at 25 DAS resulted in maximum gross return, net return and benefit-cost ratio It is obviously due to higher yield with this treatment as well as due to lower cost of cultivation.

Nutrient uptake:

Crop geometry of 60 x 30 cm with two intercultivations recorded highest nitrogen uptake which was at par with the same crop geometry when coupled with pre-emergence application of herbicide as well as the crop geometry of 45 x 40 cm or 60 x 30 cm with the herbicide application at 20 DAS (Table 4). The crop geometry of 60 x 30 cm along with pre-emergence application of herbicide + one intercultivation at 25 DAS recorded the highest nitrogen uptake at 40 DAS, 60 DAS and at harvest. Favourable influence of the crop geometry of 60 x 30 cm on nutrient uptake might be due to better absorption and accumulation of higher nutrient content in the produced biomass. Besides this, the crop canopy produced with 60 x 30 cm spacing might have had a physiological advantage in absorption, translocation and assimilation of nutrient, resulting in improved uptake. The highest phosphorus uptake was recorded with all the crop geometries with the pre-emergence application of pendimethalin + one intercultivation of 25 DAS at all the stages of crop growth. The highest potassium uptake was

Table 3 : Yield attributes, yield and economics of sunflower as influenced by crop geometry, weed control methods and nutrient levels (mean of 2 years data)

Treatments	Head diameter (cm)	No. filled seeds head $^{-1}$	Wt. of filled seeds head $^{-1}$	Filling %	Test weight (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Oil content (%)	HI	Economics: Gross returns (Rs ha^{-1})	Net returns Rs ha^{-1})	B.C Ratio
Crop geometry and weed control method												
G_1W_1	14.7	510	26	72	3.96	1588	2237	31.4	0.42	31768	18421	2.38
G_1W_2	15.2	543	24	77	4.01	1575	2220	31.7	0.41	31510	18864	2.49
G_2W_1	15.8	614	26	79	4.09	1695	2427	31.2	0.41	33927	20580	2.54
G_2W_2	14.7	581	26	81	4.15	1776	2284	31.1	0.44	35523	22876	2.81
G_3W_1	13.7	511	25	75	3.96	1764	2341	30.7	0.38	28718	15372	2.15
G_3W_2	15.3	500	22	78	4.02	1720	2189	31.5	0.41	29284	159375	2.19
S.E. $\pm$	0.76	10.9	-	1.63	0.023	19.8	67.8	0.38	0.008	393	393	0.03
C.D. (P=0.05)	NS	48	0.7	NS	0.07	62	213	NS	NS	1242	1242	0.09
Nutrient levels												
N_1	14.4	529	24	75	3.94	1563	2351	31.2	0.40	31269	18973	2.53
N_2	14.7	559	26	80	4.11	1703	2317	31.4	0.42	34073	21026	2.61
N_3	15.7	540	25	76	4.05	1500	2181	31.1	0.41	30023	16026	2.13
S.E. $\pm$	1.2	12.1	0.37	0.55	0.02	17.7	36.7	0.32	0.005	355	355	0.027
C.D. (P=0.05)	NS	NS	1.1	1.6	0.06	51	107	NS	NS	1037	1037	0.07

NS=Non-significant

recorded with all crop geometries coupled with pre-emergence application of pendimethalin + one intercultivation at 25 DAS at almost all stages of crop growth.

Post harvest soil fertility status:

The highest quantity of soil available nitrogen was recorded with the crop geometry of 60 x 30 cm along with pre-emergence application of pendimethalin + one intercultivation at 25 DAS. The highest quantity of soil available phosphorus was noticed with the crop geometry of 60 x 30 cm along with the pre-emergence application of pendimethalin + one intercultivation at 25 DAS which was comparable to 75 x 24 cm crop geometry with the same weed control method. The maximum post harvest soil available potassium was recorded with the crop geometry of 75 x 24 cm along with two intercultivations at 25 and 45 DAS which was however, comparable to the same crop geometry with pre-emergence application of pendimethalin + one intercultivation at 25 DAS and with crop geometry of 60 x 30 cm with herbicide + one intercultivation.

Performance of sunflower under nutrient levels

Growth:

Plant height progressively increased with increase in nutrient levels. At all the stages of crop growth the tallest plants were produced with 150 per cent recommended dose of nutrient while the least plant height was associated with 100 per cent recommended dose of nutrients (Table 1). The increase in plant height with increased nutrient levels might be due to the fact that the nutrient helped in cell elongation, which finally resulted in a better plant height. Leaf area index at different stages was significantly influenced by different nutrient levels. Relatively higher or comparable leaf area indices were associated with 125 per cent recommended dose of nutrient compared to 150 per cent recommended dose of nutrient while in most of the stages, the lowest leaf area index was obtained with 100 per cent recommended dose of nutrient. Increase in leaf area index with increased nutrient up to an optimum level was evidently due to favourable effect of nutrient on cell enlargement, resulting in larger leaves (Hocking *et al.,* 1987; Mohanamba, 1992; Tomar *et al.,* 1997). Maximum drymatter production at 20 DAS was obtained with 125 per cent recommended dose of nutrient which was at par with 150 per cent recommended dose of nutrient. At 40 DAS, 150 per cent recommended dose of nutrient resulted in maximum drymatter production. At 60 DAS and at harvest, 125 per cent recommended dose of nutrient produced maximum drymatter but was at par with the 150 per cent recommended dose of nutrient. Application of 100 per cent recommended dose of nutrient accounted for the least drymatter production at all the stages of crop growth. Adequate supply of nutrient might have helped in increased plant height and leaf area due to favourable effect on cell enlargement and development of larger leaves. These

Table 4 : Nutrient uptake and Post harvest soil fertility status (Kg ha^{-1}) of sunflower as influenced by crop geometry, weed control methods and nutrient levels (mean of 2 years data)

Treatments	N uptake (kg ha^{-1})				P uptake (kg ha^{-1})				K uptake (kg ha^{-1})				Post harvest soil fertility status		
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	N	P_2O_5	K_2O
Crop geometry and weed control method															
G_1W_1	5.54	21.8	43.4	53.4	2.09	5.55	7.54	10.2	13.6	38.2	44.6	53.4	163	27.6	222
G_1W_2	5.94	22.0	43.7	56.1	2.17	5.98	8.64	11.3	14.2	38.4	45.6	55.1	172	28.1	224
G_2W_1	5.93	22.8	43.8	56.6	1.78	5.56	8.66	11.3	13.6	36.8	45.9	56.9	165	30.4	229
G_2W_2	5.91	24.7	45.5	57.9	1.66	6.29	10.4	13.8	15.2	39.9	45.0	58.3	176	32.9	236
G_3W_1	5.6	22.4	42.1	53.0	1.41	5.07	8.85	11.8	11.9	34.5	41.5	54.8	164	30.9	239
G_3W_2	5.86	22.5	43.1	55.9	1.74	6.3	7.88	10.2	12.9	38.1	43.3	56.4	169	32.2	241
S.E. ±	0.099	0.118	0.75	0.79	0.09	0.098	0.18	0.18	0.29	0.67	0.56	0.3	1.1	0.36	1.52
C.D. (P=0.05)	NS	0.37	NS	2.51	0.29	0.31	0.58	0.56	0.93	NS	1.76	0.94	3.0	1.2	5.0
Nutrient levels															
N_1	5.28	20.1	42.0	53.3	1.70	4.75	7.05	9.39	12.8	34.0	41.5	52.7	156	26.3	223
N_2	5.74	22.8	44.1	58.5	1.94	6.36	9.83	12.8	13.6	38.4	44.9	55.5	168	31.9	234
N_3	6.36	25.2	45.5	50.9	1.79	6.26	9.11	12.33	14.3	40.6	46.4	57.8	181	32.5	238
S.E.±	0.062	0.09	0.32	0.74	0.05	0.07	0.114	0.14	0.18	0.38	0.56	0.31	0.8	0.22	0.61
C.D. (P=0.05)	0.18	0.26	0.94	2.17	0.15	0.22	0.33	0.41	0.53	1.11	1.64	0.92	2.0	0.6	2.0

NS=Non-significant

effects ultimately might have resulted in a higher photosynthetic efficiency, thereby accounting for higher drymatter accumulation. Enhanced drymatter production with increased nutrient was also reported by Mohanamba (1992) and Tomar *et al.* (1997). Application of 100 per cent recommended dose of nutrient resulted in the earliest flowerings, while 150 per cent recommended dose of nutrient delayed the flowering. The recommended dose of nutrient coupled with a higher availability of soil moisture due to higher amount of rainfall might have helped in early cessation of vegetative growth, leading to early switching over to reproductive phase, thus resulting in early flowering. Similarly, these favourable conditions might have helped in non-significant differences in number of days to maturity.

Weed density and weed drymatter:

Significantly least number of weeds was recorded with 100 per cent recommended dose of nutrient followed by 125 per cent recommended dose of nutrient while 150 per cent recommended dose of nutrient registered significantly higher weed count at all the crop growth stages (Table 2). Due to higher availability of nutrient through higher nutrient dose, the weed growth was higher, leading to a higher weed count with successive increment in nutrient levels. Application of 100 per cent recommended dose of nutrient registered the least drymatter of weeds followed by 125 per cent recommended dose of nutrient at all the stages.These variations might be attributed to the number of weeds as well as the weed flora that existed at different stages.

Yield attributes, yield and economics:

Each and every successive increase in the nutrient level resulted in a corresponding increase in the flower head diameter and it was found to be highest with 150 per cent recommended dose of nutrient while, it was lowest with the 100 per cent recommended dose of nutrient (Table 3). A better crop growth might have led to better translocation of photosynthates from source to sink resulting in larger size of flower head. These results are in conformity with Singh and Pacheria (1981). The highest number of filled seeds per head was recorded with 125 per cent recommended dose of nutrient. The maximum weight of filled seeds was obtained with 125 per cent recommended dose of nutrient followed by 150 per cent recommended dose of nutrient. In general, the performance of the crop was poor with 100 per cent recommended dose of nutrient. Significantly higher filling percentage was registered with 125 per cent recommended dose of nutrient followed by 150 per cent recommended dose of nutrient. Test weight was higher with 125 per cent recommended dose of nutrient which differed significantly from other levels. The 100 per cent recommended dose of nutrient accounted for the least test weight which was significantly inferior to other nutrient levels. These results are in agreement with the findings of Hiray *et al.* (1992) and Mohanamba (1992).

Highest seed yield was produced with 125 per cent recommended dose of nutrient which was significantly superior to other nutrient levels. Significantly lower seed yield was obtained with 150 per cent and 100 per cent recommended dose of nutrient. Application of 125 per cent recommended dose of nutrient resulted in better growth and yield attributes *viz.,* leaf area index, drymatter production, number and weight of filled seeds per head, higher filling percentage and test weight which resulted in a higher seed yield with this nutrient level compared to other lower or higher levels. Similar findings were reported by Tomar *et al.* (1997) and Shrivastava *et al.* (1998). The highest stalk yield was obtained with 125 per cent recommended dose of nutrient,while the least stalk yield was registered with 150 per cent recommended dose of nutrient, the increase in stalk yield with N_2 level might be attributed to higher leaf area index and drymatter production which ultimately resulted in higher stalk yields. These results are in conformity with the findings of Mishra *et al.* (1995) and Poonguzhalan *et al.* (2002). Higher oil content was noticed with 100 per cent recommended dose of nutrient followed by 125 per cent recommended dose of nutrient while 150 per cent resulted in the least oil content.

Crop geometry of 60 x 30 cm with pre-emergence application of pendimethalin + one intercultivation at 25 DAS coupled with 125 per cent recommended dose of nutrients resulted in maximum gross return, net return and benefit-cost ratio. It is obviously due to higher yield with this treatment as well as due to lower cost of cultivation. The lower values of net return and benefit-cost ratio in combination with 150 per cent recommended dose of nutrient might be attributed to the higher cost of cultivation incurred under this treatment compared to other nutrient levels.

Nutrient uptake and post harvest soil fertility status:

The nitrogen uptake of sunflower increased with increasing levels of nutrient and the highest uptake was recorded with 150 per cent recommended dose of nutrient at all the stages of crop growth. Higher uptake of nitrogen with increasing levels of nutrient was also reported by Reddy (1998). In case of phosphorus uptake 125 per cent and 150 per cent recommended dose of nutrient resulted in the highest phosphorus uptake. These results are in conformity with Sarmah *et al.* (1995). As in case of N uptake, the potassium uptake was higher with 150 per cent recommended dose of nutrient at all stages of crop growth. These results are in agreement with those of Poonguzhalan *et al.* (1996).

Higher levels of nutrient application to the crop resulted in higher levels of soil nutrient status after harvest the crop. Significantly higher soil available nitrogen, phosphorus and potassium were observed with 150 per cent recommended dose of nutrient followed by 125 per cent recommended dose of nutrient.

In conclusion, it could be inferred from the investigation that sowing of sunflower at a spacing of 60 x 30 cm along with the pre-emergence application of pendimethalin + one intercultivation at 25 DAS and application of 125 per cent recommended dose of nutrients (100 kg N, 62.5 kg P_2O_5 and 37.5 kg K_2O ha^{-1}) was found to be the best package of agro-techniques for rainfed sunflower on vertisols of Southern Agro-climatic zone of Andhra Pradesh, for realizing higher productivity and economic returns.

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