Effects of Macronutrients on Seed Quality and Profitability Analysis of Sunflower Production in Northwest Pakistan

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ABSTRACT

Potassium (K) and phosphorus (P) application to sunflower (*Helianthus annus* L.) reduced cost of production, increased seed oil and protein concentration, yield and net returns on the K and P deficient soils in Northwest Pakistan. Field experiment was conducted at the New Developmental Research Farm of NWFP (North West Frontier Province) Agricultural University Peshawar, Pakistan during summer 2006. The experiment was carried out in a randomized complete block design with split plot arrangements using three replications. Six levels of K (0, 25, 50, 75, 100 and 125 kg ha^{-1}) were kept in main plots while four levels of P (0, 45, 90 and 135 kg ha^{-1}) were kept in sub-plots. Increase in K and P levels enhanced seed oil concentration, on the other hand, increase in P level increased seed protein concentration but increase in K level decreased seed protein concentration. Both oil and protein yields per unit area increased significantly with increase in K and P levels. The increase in oil and protein yields of sunflower was mainly attributed to the improvement in yield components and significant increase in seed yield. The highest net returns of Rs. 25268 (grain yield basis) and Rs. 31274 (oil yield basis) was obtained from those plots that received a combination of 100 kg K + 45 kg P ha^{-1}. Application of 100 kg K ha^{-1} + 45 kg P ha^{-1} was therefore, recommended for profitable sunflower production in the agro-climatic conditions in Northwest Pakistan.

Key words: sunflower, potassium, phosphorus, oil, protein, economic analysis

INTRODUCTION

Pakistan is facing a huge shortage of edible oil for a long time. In addition to rapid rise in population and living standard of people, lack of high yielding varieties and lower production per unit area are the major constraints in edible oil status in the country. Domestic oil production hardly meets 30 % of the national demand whereas remaining 70 % is met through the import by spending huge foreign exchange (Amanullah and Hatam, 2001). Sunflower (*Helianthus annus* L.) is the third major supplier of edible oil in the world after soybean and groundnut (Meric et al., 2003). It occupies an important place among oilseed crops in the world market and its production has multiplied by approximately 1.8 during last 20 years (Pouzet and Delplancke, 2000). The total area under oilseed crops in Pakistan during 2005-06 was 279.8 thousand hectares while production during the same period was 238.1 thousand tones with an average yield of 851.00 kg ha^{-1}. In NWFP, area under production was 20.7 thousand hectares, production was 9.0 thousand tones and the average yield was 435 kg ha^{-1}. Sunflower was grown on total area of 325082 thousand hectares in the country with a total production of 348275 tones with an average seed yield of just 1071 kg ha^{-1} (MINFAL, 2006). Imbalanced fertilizer use especially in terms of phosphate (P) compared with other nutrients, has created concern in Pakistan as it may affect overall agricultural productivity and economic growth (FAO, 2007).

Sunflower had shown differential response to K and P fertilization in different environments. Sunflower seed oil concentration depends on genotype, but it may be expressed differently under different environments (Zheljazkov et al., 2008). Potassium application at the rate of 300 kg K_2O ha^{-1} increased oil content and decreased protein content significantly (Ahmad et al., 1999). Seed yield and oil contents increased at 100 kg K ha^{-1} but both these parameters were decreased beyond this limit (Ayub et al., 1999). Potassium application significantly affected seed protein concentration of autumn sunflower but differences were non-significant in spring season crop but the seed oil concentration was significantly affected by K application in both the seasons (Ahmad et al. (2001). Lower oil concentration in sunflower seeds was observed at low K supply as compared to oil concentration obtained at higher K supply (Abbadi et al., 2008).

Increase in P levels had no significant effects on oil seed concentration of sunflower but increased seed N content and yield as compared to control (Muralidharudu et al., 2003). Higher P levels increased the nitrogen use efficiency and yield (Zubillaga et al., 2002). Significant increase in seed yield was noted with P application as compared to control (Shivaprasad et al., 1996; Sarkar et al., 1995). Phosphorus uptake increased with higher P level of 100 kg ha^{-1} but the hieghest seed yield was obtained with 75 kg P ha^{-1} and further increase in P level did not increased yield (Shanty et al., 2002).

Application of a unit fertilizer is economical, if the value of the increase in the crop yield due to the quantity of fertilizer added is greater than the cost of fertilizer used. If a unit of fertilizer does not increase the yield enough to pay for its cost, its application will not be economical and will not return profit even after a constant increase in the yield (Singh, 2004). The application of essential plant nutrients in optimum quantity and right proportion is the key to increased and sustained crop production (Cisse and Amar, 2000). Farmers in Pakistan are profit-oriented, and therefore, they are interested in net returns than the gross returns. In practice, not all farmers, however, can aim for the largest net return because of the generally larger costs involved to other risks associated with farming (Saleem et al., 1986). According to Bhatti (2006) the risk factors involved in agriculture, a VCR of 2 is recommended for farmers using high technology in Pakistan. A VCR of 2 represents 100 % return on the money invested on fertilizer. For farmers with low technology, with no credit available to them or limited capital, a fertilizer rate giving a VCR grater than 2 should be recommended.

Studies on the combine K and P fertilization on sunflower seed yield, quality and economic analysis are lacking in the world. Keeping in view the importance of K and P application to sunflower, this experiment was therefore; carried out with an objective to find out the best K + P combination to increase oil and protein concentration in seeds, increase oil and protein yield as well as net returns in the study area.

MATERIALS AND METHODS

Site Description

Field experiment was conducted at the Agriculture Research Farm of the NWFP Agricultural University, Peshawar during summer 2006. The experimental farm is located at 34.01^{o} N latitude, 71.35^{o} E longitude at an altitude of 350 m above sea level in Peshawar valley. Peshawar is located about 1600 km north of the Indian Ocean and has continental type of climate. The research farm is irrigated by Warsak canal from river Kabul. Soil texture is clay loam, low in organic matter (0.87 %), extractable phosphorus (6.57 mg kg^{-1}), exchangeable potassium (121 mg kg^{-1}), and alkaline (pH 8.2) and is calcareous in nature (Amanullah et al., 2009).

Experimentation

Seed quality and economics response of sunflower (cv. Hysun-33) was studied in a field experiment in randomized complete block design with split plot arrangement using three replications. Plot size of 4.2 m x 4 m comprising 6 rows with row to row distance of 70 cm was used. Six levels of potassium (K) [K_1 = 0' K_2 = 25, K_3 = 50, K_4 = 75, K_5 = 100, and K_6 = 125 kg ha^{-1}] as potassium sulphate (50 % K_2O) were kept in main plots and four levels of phosphorus (P) [P_1 = 0' P_2 = 45, P_3 = 90, and P_4 = 135 kg ha^{-1}] as single super phosphate (18 % P_2O_5) were kept in sub plots. Seeds were sown on well-prepared seedbed in 70 cm spaced rows using seed rate of 6 kg ha^{-1}. The whole of the P and K-fertilizers was applied at the time of seedbed preparation. A basal dose of nitrogen (N) at the rate of 120 kg N ha^{-1} as urea (46 % N) was applied in two equal splits i.e. 50 % each at sowing time and with 1st irrigation (15 days after emergence). All the agronomic practices i.e. irrigation, weeding, hoeing and spraying was carried out uniformly for all the experimental plots.

Data on seed yield was recorded by harvesting the four central rows in each sub plot and after drying it up to constant weight their seed was removed, weighed and converted to kg ha^{-1}

$$\text{Seed yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield (kg)} \times 10{,}000 \text{ m}^2}{\text{Row length (m)} \times \text{No of rows} \times \text{R-R (m)}}$$

Percent oil and protein concentration in sunflower seeds was determined with the help of Near Infra-Red Reflectance Spectroscopy (Foss-6500) system at Oilseed Quality Lab, Crop Breeding Division, NIFA (Nuclear Institute of Food and Agriculture), Tarnab, Peshawar. Oil and protein yield (kg ha^{-1}) was determined using the following formulae:

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)} \times \text{Percent oil concentration in seeds}}{100}$$

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield (kg ha}^{-1}\text{)} \times \text{Percent protein concentration in seeds}}{100}$$

Statistical analysis

The data on seed oil and protein concentration, and oil and protein yield was subjected to analysis of variance (ANOVA) according to the methods described in Steel and Torrie (1980) and treatment means were compared using the least significant difference (LSD) at $p \leq 0.05$.

Economic Analysis

Net Return (the value of the increased yield produced as a result of fertilizers applied, less the cost of fertilizer) and *Value Cost Ratio* (the ratio between the value of the additional crop yield and the cost of fertilizer) was determined according to the procedures described by Saleem et al. (1986) and Bhatti (2006).

RESULTS AND DISCUSSION

Oil and protein concentration in seeds

Perusal of the data indicated that both K and P levels had significant effects while their interaction (K x P) had had non-significant effects on oil concentration in sunflower seeds (Table I). The highest oil concentration of 43.8 % was noted when K was applied at the highest rate of 125 kg K ha^{-1}, followed by 42.9 % with 100 kg K ha^{-1} (43.1 %), whereas the lowest seed oil concentration (37.5 %) was obtained from the K-control plots (no K applied). Percent oil concentration in seeds showed positive association with increase in K levels. Ahmad et al. (2001) and Ayub et al. (1999) noted significant increase in seed oil concentration in sunflower with K application. Ahmad et al. (1999) found the highest oil concentration of 40.83 % with 300 kg K_2O ha^{-1} in sunflower seeds but was statistically at par with application of 150, 200 or 250 K_2O ha^{-1}. They reported the lowest oil concentration (39.50 %) without K fertilization that however, did not significantly differ when compared to oil concentration obtained with 50 K_2Oha^{-1}. Abbadi et al. (2008) found significantly lower oil concentration in sunflower seeds at low K supply as compared to oil concentration obtained at higher K supply. Our results are incontrast to those of Glas et al. (1988) and Curric (1988) who reported negative influence of K application on seed oil concentration in sunflower. The discepancy in our results and those of Glas et al. (1988) and Curric et al. (1988) might be due to the difference in fertility status of soil, climatic condition or genetic make up of the species used. According to Zheljazkov et al. (2008) sunflower seed oil concentration depends on genotype, but it may be expressed differently under different environments. On the other hand, Guar et al. (1987) reported that application of K had no significant effects on seed oil concentration of sunflower.

Oil concentration in seeds increased significantly when P was applied at the two higer levels of P (90 and 135 kg P ha^{-1}) as compared to the plots applied with the lowest level of P (45 kg P ha^{-1}) and the P-control plots (Table I). These results are in contrast with those of Muralidharudu et al. (2003) who found nonsignificant differences in seed oil concentration in sunflower grown in different fertility soils with increased level of P application. The discepancy in our results with those of Muralidharudu et al. (2003) might be due to the difference in fertility status of soil, climatic condition or genetic make up of the species used. Interactive effect of K x P had no significant effects on seed oil concentration. However, increase in the levels of both K and P increased seed oil concentration as compared with K and P-control plots.

Perusal of the data indicated that K and P levels as well as K x P had significant effects on seed protein concentration in sunflower- (Table II). Among the K levels, the highest protein concentration of 24.5 % was noted when K was not applied (K-control plots) whereas the lowest protein concentration of 22.1 % was obtained from the plots applied with the highest rate of 125 kg K ha^{-1} being at par with 100 kg ha^{-1}(22.2 %). Protein concentration in sunflower seeds showed negative association with oil concentration and decreased significantly with increase in K levels. Ahmad et al. (1999) and Choudhry and Mushtaq (1999) reported slight to significant reduction in seed protein concentration with K application as compared to control. According to Ahmad et al. (1999) maximum reduction in protein concentration in sunflower seeds occurred when K was applied at the rate of 200 kg K_2O ha^{-1} which was statistically equal to all K levels except 50 kg K_2O and control.

Among the P levels, the highest protein concentration of 23.2 % was noted when P was at the highest rate of 135 kg ha^{-1} whereas the lowest protein concentration of 22.5 % was obtained from the P-control plots. In contrast to K levels, protein concentration showed positive association with increase in P levels but it was at par between the two highest levels of P application indicating further increase in P levels would not improve the protein concentration in sunflower seeds. Fertilization of sunflower with higher P levels might have increased the nitrogen use efficiency (Zubillaga et al., 2002) which extended the growth period (data not shown) that resulted in the higher protein concentration in sunflower seeds. Muralidharudu et al. (2003) found higher N concentration in sunflower seeds with increase in P level. Seed protein concentration increased with increase in P levels and decreased with increase in K levels resulting in significant K x P interaction (Table II). The decrease in protein concentration with higher K levels and lower P levels might be due the increase in oil concentration of sunflower which showed negative association with protein concentration. Ahmad et al. (2001) found that K application significantly affected seed protein concentration of autumn sunflower but differences were non-significant in spring season crop.

Oil and protein yields

Perusal of the data indicated that K and P levels as well as K x P interaction had had significant effects on oil yield of sunflower (Table III). Among the K levels, the highest oil yield of 618 kg ha^{-1} was obtained when K was applied at the rate of 100 kg K ha^{-1}, followed by 125 kg K ha^{-1} (585 kg oil ha^{-1}) being at par with 75 kg K ha^{-1} (562 kg oil ha^{-1}), whereas the lowest oil yield (417 kg ha^{-1}) was obtained from the K-control plots being at par with 452 kg oil ha^{-1} recorded with the lowest rate of 25 kg K ha^{-1}. Among the P levels, the highest oil yield of 626 kg ha^{-1} was obtained when P was applied at the highest rate of 135 kg K ha^{-1}, followed by 90 kg K ha^{-1} (5847 kg oil ha^{-1}) but the lowest oil yield of 372 kg ha^{-1} was obtained from the P-control plots. The increase in oil yield with increase in K and P levels was due to the higher seed yield of sunflower (data not shown). Abbadi et al. (2008) reported significantly lower oil yield because of lower seed oil concentration and lower seed yield obtained at low K supply as compared to higher oil yield at higher K supply. Zheljazkov et al. (2008) found a significant variation of 406-1166 kg oil ha^{-1} among different sunflower hybrids across various sites. They reported that although N application reduce oil concentration in sunflower seeds but because of higher seed yields, oil yields ha^{-1} increased significantly with higher N rates.

Generally the trend in oil yield increased with increase in K as well as P levels but the magnitude varied with different K and P levels resulting in significant K x P interaction (Table III). Each level of P resulted in highest oil yield when applied with 100 kg K ha^{-1}; in contrast, the P-control plots gave maxim oil yield when applied with 75 kg K ha^{-1}. Increase in K level beyond 100 kg ha^{-1} did not increased oil yield significantly when applied with the two higher levels of P; in contrast, the lower rate of 45 kg P ha^{-1} drastically declined oil yield when applied with the highest rate of 125 kg K ha^{-1}. The increase in protein yield with increase in K and P levels was due to the higher seed yield of sunflower (data not shown). Muralidharudu et al. (2003), Shivaprasad et al. (1996) and Sarkar et al. (1995) reported significant increase in seed yield of sunflower with K and P application as compared to control.

Perusal of the data indicated that K and P levels as well as K x P interaction had significant effects on protein yield (Table IV). Among the K levels, the highest protein yield of 320 kg ha^{-1} was obtained when K was applied at the rate of 100 kg K ha^{-1} being at par with protein yield obtained with 75 (299 kg protein ha^{-1}) and 125 kg K ha^{-1} (295 kg protein ha^{-1}), whereas the lowest protein yield of 273 kg ha^{-1} was obtained from the K-control plots being at par with protein yield obtained with 25 and 50 kg K ha^{-1} i.e. 275 and 281 kg protein ha^{-1}, respectively. Among the P levels, the highest protein yield of 349 kg ha^{-1} was obtained when P was applied at the highest rate of 135 kg K ha^{-1}, followed 325 kg protein ha^{-1} with 90 kg K ha^{-1} and the lowest protein yield of 206 kg ha^{-1} was obtained from the P-control plots. Fertilization of sunflower with higher levels of K and P application might have increased the uptake and effectiveness of N and other nutrients (Muralidharudu et al., 2003), that extended the growth period, number of leaves per plant and seeds per head, head size as well as grain weight that resulted in seed yield (data not shown) and so increased oil yield per unit area. These results are in agreement with those of several researchers (Ayub et al., 1999; Muralidharudu et al., 2003) who noted that sunflower yields increased significantly while increasing levels of K and P fertilization. Shanty et al. (2002) reported that P uptake increased significantly when P was applied at the highest rate of 100 kg P ha^{-1} but the hieghest seed yield from suflower was when P was applied at the rate of 75 kg P ha^{-1}.

Generally the trend in protein yield increased with increase in both K and P levels but the magnitude varied with different K and P levels resulting in significant K x P interaction (Table IV). Each level of P application resulted in highest protein yield when applied with 100 kg K ha^{-1}; in contrast, the P-control plots gave maxim protein yield when applied with 75 kg K ha^{-1}. Increase in K level beyond 100 kg ha^{-1} did not increased oil yield significantly when applied with the two higher levels of P; in contrast, the lower rate of 45 kg P ha^{-1} drastically declined protein yield when applied with the highest rate of 125 kg K ha^{-1}. The increase in protein yield with higher K and P levels might be due the increase seed yield of sunflower that showed showed positive association with protein yield.

Economic analysis

On the basis of grain yield, he highest a net return of Rs. 25268/- per hectare was obtained from those plots that received 100 kg K + 45 kg P ha^{-1}, followed by Rs. 22543/- per hectare in the plots applied with 100 kg K + 90 kg P ha^{-1}. The highest value cost ratio (VCR) 2.1 was calculated each for the plots applied with 0 kg K + 90 kg P ha^{-1} and 100 kg K + 45 kg P ha^{-1}, followed by VCR of 1.7 for the plots applied with 0 kg K + 90 kg P ha^{-1} (Table V). It is clear from net benefit curves, that in the absence of K (Fig 1), and application of the two lower doses of potassium i.e. 25 kg K ha^{-1} (Fig 2) and 50 kg K ha^{-1}, the net returns increased with increase in P level up to the highest level of 135 kg P ha^{-1}. Combine application of 50 kg K ha^{-1} + 135 kg P ha^{-1} could result more benefit from oil yield as compared to seed yield because of significant increase in seed oil concentration. Application of potassium at the rate of 75 kg K ha^{-1} (Fig 4), the net returns increased with increase in P level up to 90 kg P ha^{-1} and further increase in P level up to the highest level (135 kg P ha^{-1}) decreased the net returns. Combine application of 75 kg K ha^{-1} + 90 kg P ha^{-1} could result more benefit from oil yield as compared to seed yield because of significant increase in seed oil concentration. Application of potassium at the rate of 100 kg K ha^{-1} (Fig 5), the highest net returns was obtained when P was applied at the lowest level of 45 kg P ha^{-1} and beyond this level the net returns decreased. Combine application of 100 kg K ha^{-1} + 45 kg P ha^{-1} resulted in more benefit. But application of potassium the highest rate of 125 kg K ha^{-1} (Fig 6), the highest net returns was obtained when P was applied at the lowest level of 90 kg P ha^{-1} and beyond this level the net returns decreased indicating that combine application of 125 kg K ha^{-1} + 90 kg P ha^{-1} could result in more benefit in the study area.

On the basis of oil yield, the highest net return of Rs. 31274/- per hectare was obtained from those plots that received 100 kg K + 45 kg P ha^{-1}, followed by Rs. 28682/- and Rs. 28550/- per hectare in the plots applied with 100 kg K + 135 kg P ha^{-1} and 100 kg K + 90 kg P ha$^{-1,}$ respectively (Table VI). The highest value cost ratio (VCR) 2.4 was calculated for the plots applied with 100 kg K + 45 kg P ha^{-1}, followed by VCR of 1.7 for the plots applied with 100 kg K + 90 kg P ha^{-1} (Table VI). The increase in net returns obtained from the plots that received 100 kg K + 45 kg P ha^{-1} was attributed to the decline in cost of production and improvement in the yield components that increased the seed yield significantly and so net returns. The net benefit curves indicated that in the absence of phosphorus application, net returns increased with increase in potassium level up to 75 kg K ha^{-1} and further increase in K decreased net returns

(Fig 7). Application of phosphorus at the rate of 45 kg P ha^{-1} (Fig 8), 90 kg P ha^{-1} (Fig 9) and 135 kg P ha^{-1} (Fig 9) the net returns increased with increase in K level up to 100 kg K ha^{-1} and further increase in K level up to the highest level (125 kg K ha^{-1}) decreased the net returns. Combine application of 100 kg K ha^{-1} + 45 kg P ha^{-1} could result more benefit from sunflower.

CONCLUSIONS

Oil and protein concentration in sunflower seed as well as oil and protein yields improved with K and P application as compared with K and P-control plots. Oil concentration in seeds increased and protein concentration decreased with increase in K levels. Protein concentration in seeds increased with increase in P levels but oil concentration showed no response with change in P levels. The increase in oil and protein yields of sunflower depends on higher seed yield obtained with higher K and P fertilization than control. On the basis of economic analysis the highest net returns of Rs. 25268 (grain yield basis) and Rs. 31274 (oil yield basis) was obtained from those plots that received 100 kg K + 45 kg P ha^{-1}. Therefore, application of 100 kg K + 45 kg P ha^{-1} to sunflower could results in maximum net returns and is therefore, recommended for profitable sunflower production Northwest Pakistan. Further research on the combination of K and P fertilizers application to sunflower needs to be developed under different cropping systems in various agro-climatic zones of NWFP. The agriculture statistics data for the last so many years indicated that the area under sunflower cultivation is decreasing gradually in Northwest Pakistan. The government should install free oil extraction machines from sunflower seeds that will encourage the farmers to grow sunflower which will decrease the import of vegetable oil on one hand, but on the other hand, the growers could get more benefit to sell the oil than seeds.

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TABLE I

Seed oil concentration (%) in sunflower hybrid (Hysun-33) as affected by levels of potassium (K) and phosphorus (P) application

Levels of K	Levels of P (kg ha^{-1})				
(kg ha^{-1})	0	45	90	135	Mean (K)
0	37.3	37.0	37.7	38.0	37.5
25	39.3	39.0	39.3	38.7	39.1
50	39.7	39.3	40.3	41.0	40.1
75	41.3	42.0	42.7	43.3	42.3
100	42.3	43.0	43.0	43.3	42.9
125	43.3	43.7	44.0	44.3	43.8
Mean (P)	40.6	40.7	41.2	41.4	

LSD for K ($p \leq 0.05$) = 0.78
LSD for P ($p \leq 0.05$) = 0.40
LSD for K x P ($p \leq 0.05$) = ns (non significant)

TABLE II

Seed protein concentration (%) in sunflower hybrid (Hysun-33) as affected by levels of potassium (K) and phosphorus (P) application

Levels of K	Levels of P (kg ha^{-1})				
(kg ha^{-1})	0	45	90	135	Mean
0	23.5	24.6	24.7	25.3	24.5
25	23.2	23.7	23.7	24.3	23.7
50	22.5	22.5	22.6	22.6	22.5
75	22.2	22.5	22.8	22.7	22.5
100	21.8	22.1	22.4	22.5	22.2
125	21.7	22.0	22.5	22.2	22.1
Mean (P)	22.5	22.9	23.1	23.2	

LSD for K ($p \leq 0.05$) = 0.30
LSD for P ($p \leq 0.05$) = 0.12
LSD for K x P ($p \leq 0.05$) = 0.28

TABLE III
Oil yield (kg ha^{-1}) of sunflower hybrid (Hysun-33) as affected by levels of potassium (K) and phosphorus (P) application

Levels of K (kg ha^{-1})	Levels of P (kg ha^{-1})				
	0	45	90	135	Mean (K)
0	304	388	460	515	417
25	349	436	489	533	452
50	364	451	557	630	500
75	437	537	629	647	562
100	407	671	680	713	618
125	372	558	691	719	585
Mean (P)	372	507	584	626	

LSD for K ($p \leq 0.05$) = 35.84
LSD for P ($p \leq 0.05$) = 29.72
LSD for K x P ($p \leq 0.05$) = 72.80

TABLE IV
Protein yield (kg ha^{-1}) of sunflower hybrid (Hysun-33) as affected by levels of potassium (K) and phosphorus (P) application

Levels of K (kg ha^{-1})	Levels of P (kg ha^{-1})				
	0	45	90	135	Mean (K)
0	191	258	301	342	273
25	206	264	295	334	275
50	206	258	311	347	281
75	235	287	336	338	299
100	210	344	354	370	320
125	186	280	353	361	295
Mean (P)	206	282	325	349	

LSD for K ($p \leq 0.05$) = 23.73
LSD for P ($p \leq 0.05$) = 15.45
LSD for K x P ($p \leq 0.05$) = ns (non significant)

Table V

Net returns (NR) and value cost ratio (VCR) of sunflower hybrid (Hysun-33) as affected by levels of K and P application (seed yield basis)

K levels (kg ha^{-1})	P levels (kg ha^{-1})	Fertilizer cost in Pak. Rupees	Seed yield (kg ha^{-1})	Increase in seed yield over control (kg ha^{-1})	Value of increased yield @ Rs. 50/kg	Net returns (Rs. ha^{-1})	Value cost ratio
0	0	0	813	-	-	-	-
0	45	3795	1049	236	11803	8008	2.1
0	90	7590	1220	407	20363	12773	1.7
0	135	11385	1356	543	27140	15755	1.4
25	0	2075	888	75	3740	1665	0.8
25	45	5870	1118	305	15238	9368	1.6
25	90	9665	1244	431	21545	11880	1.2
25	135	13460	1376	563	28143	14683	1.1
50	0	4150	917	104	5193	1043	0.3
50	45	7945	1145	332	16577	8632	1.1
50	90	11740	1381	568	28388	16648	1.4
50	135	15535	1538	725	36248	20713	1.3
75	0	6225	1058	245	12267	6042	1.0
75	45	10020	1278	465	23272	13252	1.3
75	90	13815	1473	660	32982	19167	1.4
75	135	17610	1494	681	34030	16420	0.9
100	0	8300	961	148	7417	-883	-0.1
100	45	12095	1560	747	37363	25268	2.1
100	90	15890	1582	769	38433	22543	1.4
100	135	19685	1647	834	41680	21995	1.1
125	0	10375	859	46	2297	-8078	-0.8
125	45	14170	1277	464	23180	9010	0.6
125	90	17965	1571	758	37913	19948	1.1
125	135	21760	1623	810	40485	18725	0.9

Where

Cost of K fertilizer (SOP) = Rs. 2000 per 50 kg bag
Cost of P fertilizer (SSP) = Rs. 700 per 50 kg bag
Cost of fertilizer application = Rs. 1 per kg
Cost of fertilizer transportation = Rs. 50 per bag
Value of sunflower seed (grains) = Rs. 50 per kg

Table VI
Net returns (NR) and value cost ratio (VCR) of sunflower hybrid (Hysun-33) as affected by levels of K and P application (oil yield basis)

K levels (kg ha^{-1})	P levels (kg ha^{-1})	Fertilizer and oil extraction cost in Pak. Rupees	Oil yield (kg ha^{-1})	Increase in oil yield over control (kg ha^{-1})	Value of increased in oil yield @ Rs. 120/kg	Net returns (Rs. ha^{-1})	Value cost ratio
0	0	0	304	-	-	-	-
0	45	4183	388	84	10080	5897	1.4
0	90	8050	460	156	18720	10670	1.3
0	135	11900	515	211	25320	13420	1.1
25	0	2424	349	45	5400	2976	1.2
25	45	6306	436	132	15840	9534	1.5
25	90	10154	489	185	22200	12046	1.2
25	135	13993	533	229	27480	13487	1.0
50	0	4514	364	60	7200	2686	0.6
50	45	8396	451	147	17640	9244	1.1
50	90	12297	557	253	30360	18063	1.5
50	135	16165	630	326	39120	22955	1.4
75	0	6662	437	133	15960	9298	1.4
75	45	10557	537	233	27960	17403	1.6
75	90	14444	629	325	39000	24556	1.7
75	135	18257	647	343	41160	22903	1.3
100	0	8707	407	103	12360	3653	0.4
100	45	12766	671	367	44040	31274	2.4
100	90	16570	680	376	45120	28550	1.7
100	135	20398	713	409	49080	28682	1.4
125	0	10747	372	68	8160	-2587	-0.2
125	45	14728	558	254	30480	15752	1.1
125	90	18656	691	387	46440	27784	1.5
125	135	22479	719	415	49800	27321	1.2

Where
Cost of K fertilizer (SOP) = Rs. 2000 per 50 kg bag
Cost of P fertilizer (SSP) = Rs. 700 per 50 kg bag
Cost of fertilizer application = Rs. 1 per kg
Cost of fertilizer transportation = Rs. 50 per bag
Value of sunflower oil = Rs. 50 per kg
Cost of oil extraction = Rs. 1 per kg oil

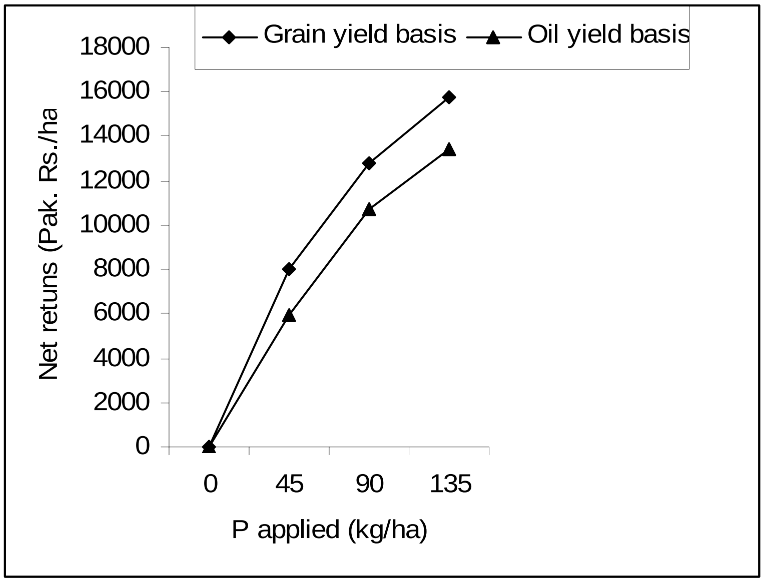

Fig 1. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when K was not applied

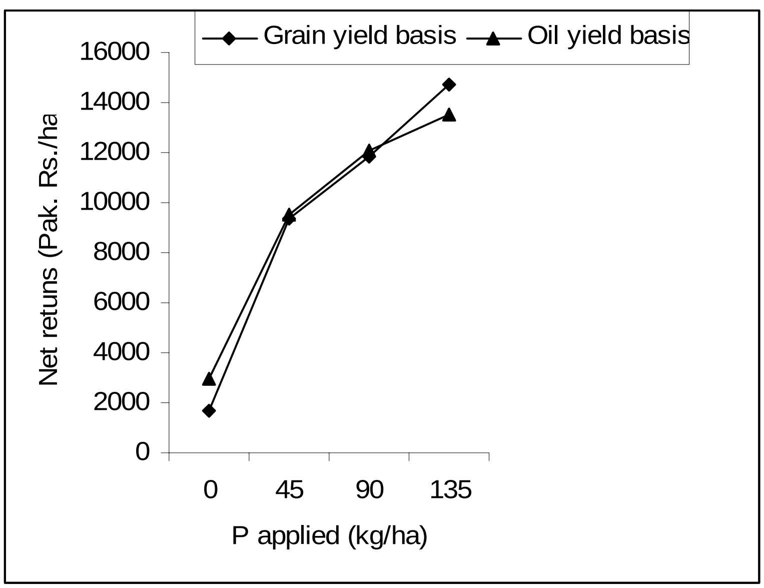

Fig 2. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 25 kg K ha^{-1}

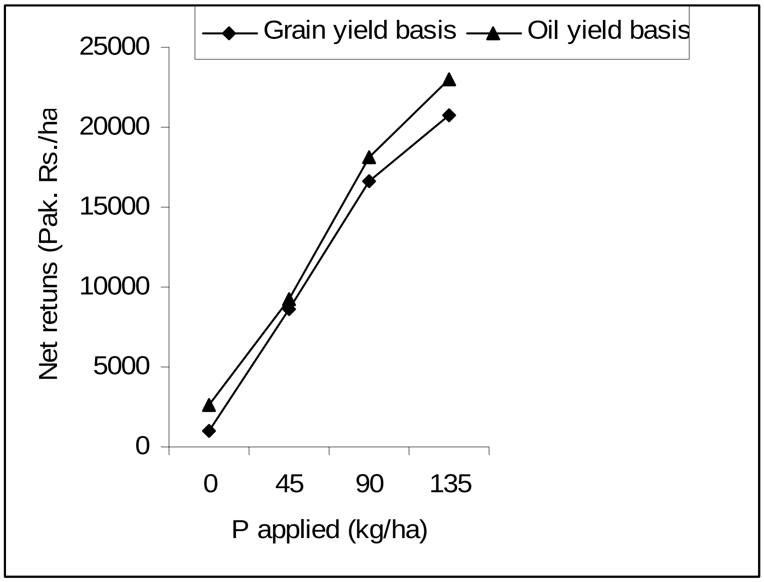

Fig 3. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 50 kg K ha^{-1}

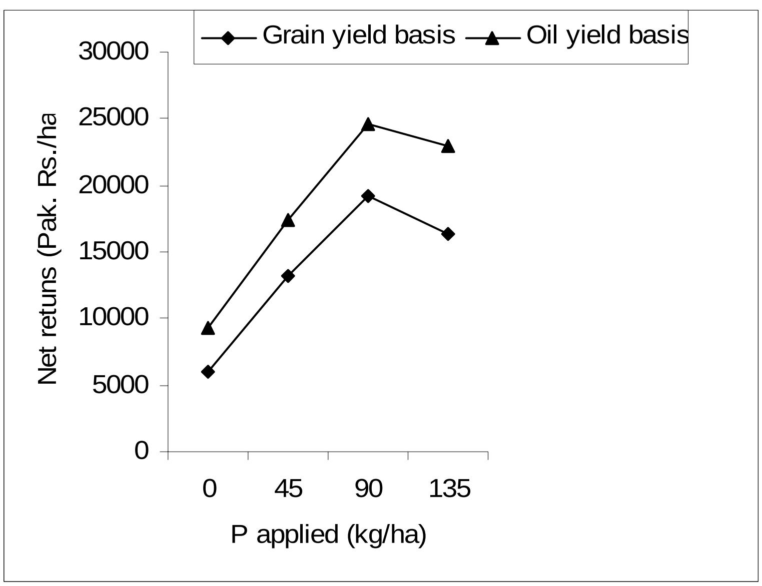

Fig 4. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 75 kg K ha^{-1}

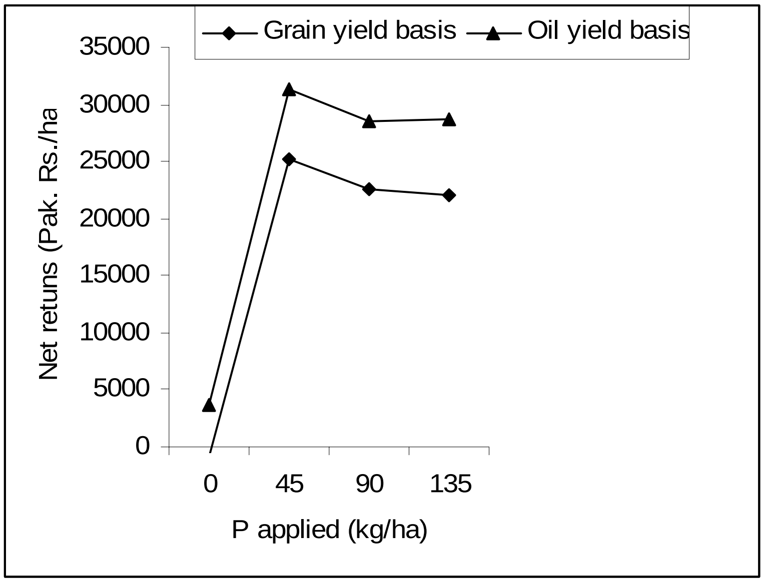

Fig 5. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 100 kg K ha^{-1}

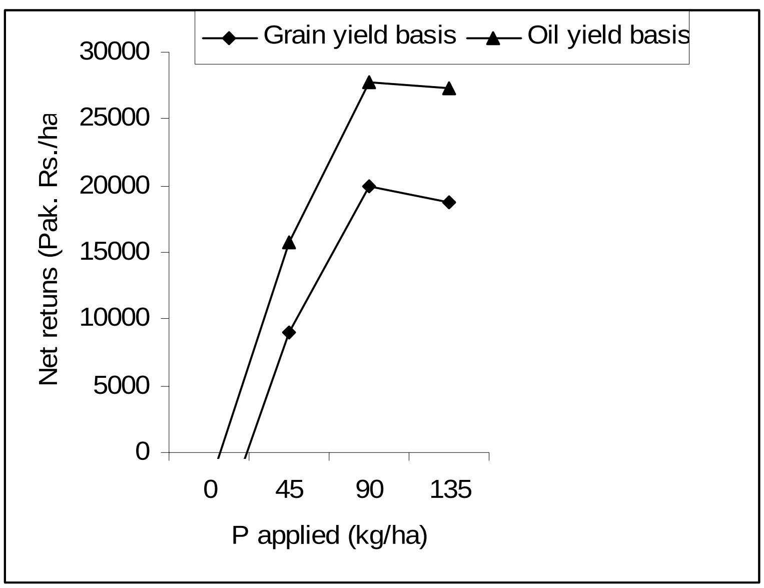

Fig 6. Impact of different P levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 125 kg K ha^{-1}

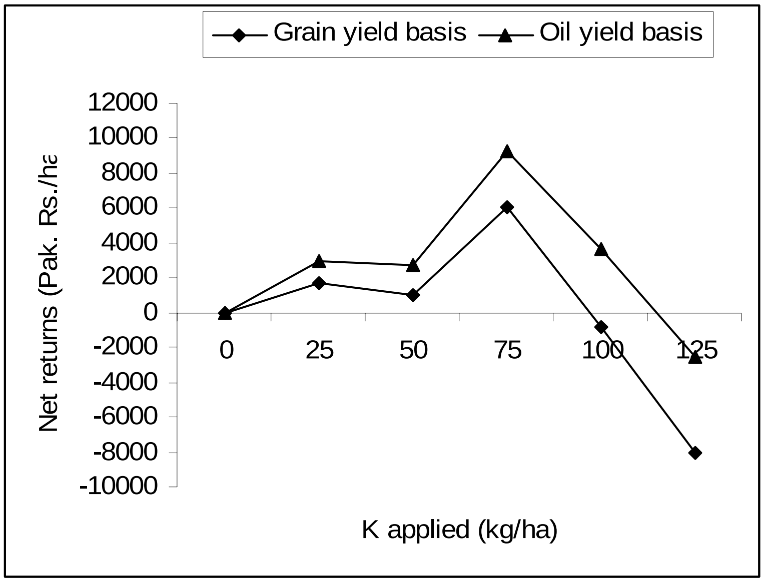

Fig 7. Impact of different K levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when P was not applied

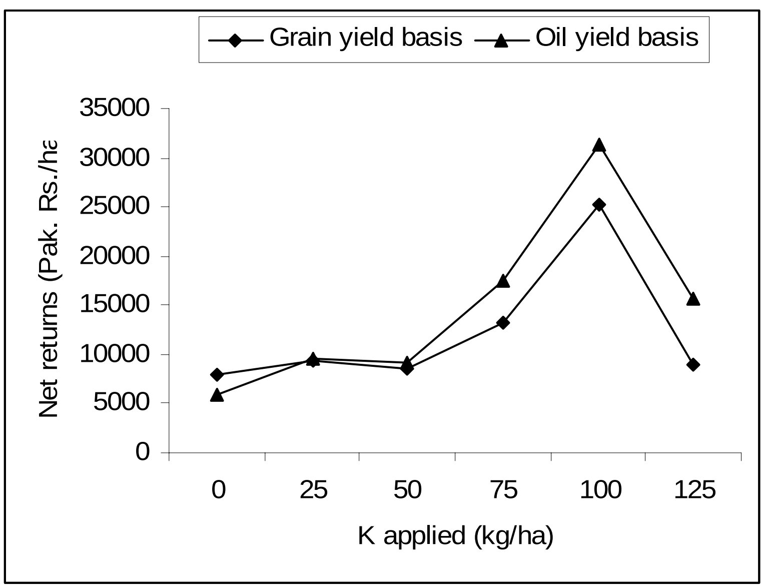

Fig 8. Impact of different K levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 45 kg P ha^{-1}

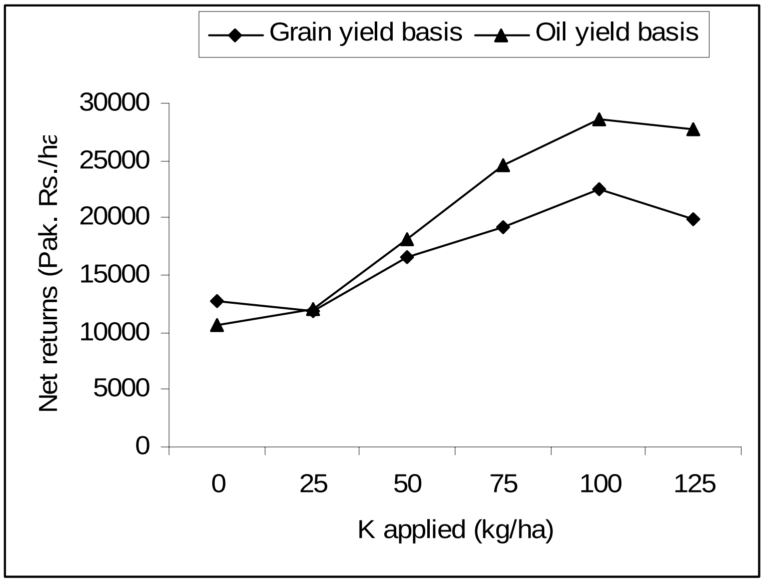

Fig 9. Impact of different K levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 90 kg P ha^{-1}

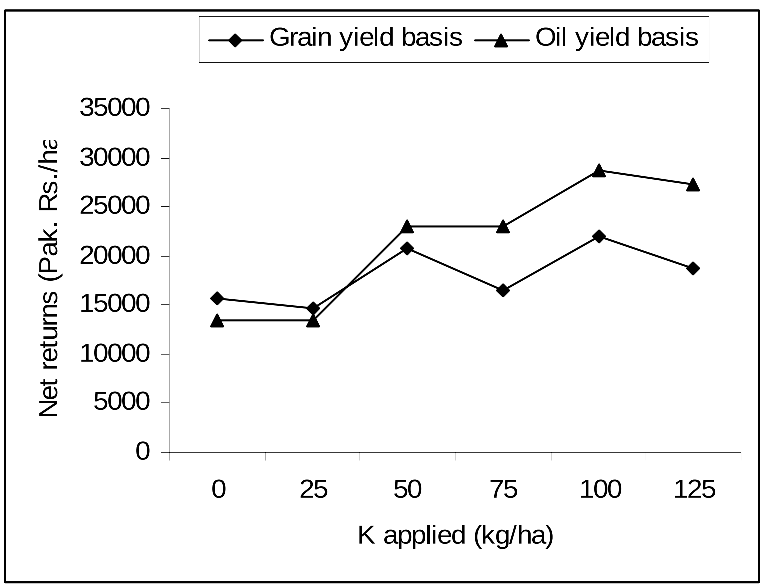

Fig 10. Impact of different K levels on the net benefit curve of sunflower hybrid (Hysun-33) on both grain and oil yields basis when applied with constant dose of 135 kg P ha^{-1}