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PRODUCTIVITY AND PROFITABILITY OF SPRING PLANTED SUNFLOWER HYBRID WITH NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZER

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ABSTRACT

A replicated field experiment was conducted during 2013 to determine the effect of omitted nutrients on productivity and profitability of sunflower at Central Research Farm under Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. The influence of nutrient omissions on the soil health was also determined. The results clearly indicated positive response of NPK fertilization to sunflower. Ample NPK (125% RDF) recorded maximum plant height (104.68 and 127.67 cm), dry matter production (74.38 and 99.79 g plant^{-1}) and leaf area index (1.73 and 1.51) at 50 and 100 days after sowing (DAS), but this treatment was statistically at par with 100% RDF ($N_{80}P_{40}K_{40}$) and differed significantly from farmer's fertilizer practice ($N_{60}P_{30}K_{30}$). Nutrient omitted plots showed significant reduction in growth attributes over ample NPK ($N_{100}P_{50}K_{50}$). But the extent of reduction was higher in plants with N omission (26.63, 36.42 and 46.33% for plant height, LAI and DMA at 100 DAS, respectively). Sunflower plants produced higher yield attributes (1129.33 seeds per capitulum, 64.41 g seed weight per capitulum and 5.73 g for 100 seed weight and seed yield (1465.15 kg ha^{-1}) of sunflower under application of $N_{100}P_{50}K_{50}$. Plants with N omission showed greater reduction in number of seeds per capitulum (27.42%), seed weight per capitulum (38.49%), 100 seed weight (10.47%) and seed yield (16.66%). Nutrient uptake was maximum (68.75, 14.47 and 79.12 kg N, P and K ha^{-1}, respectively) with ample NPK while plants with N omission showed minimum uptake (26.67, 7.53 and 30.19 kg N, P and K ha^{-1}, respectively). Actual balance of N in post-harvest soil was positive in plots fertilized with 100% RDF ($N_{80}P_{40}K_{40}$) and P and K-omitted plots. There was actual gain of P status of post-harvest soil in all the treatments, except farmer's fertilizer practice ($N_{60}P_{30}K_{30}$) and P-omitted plots. However, the actual balance of K was negative irrespective of treatments. Gross benefit: cost (B: C) ratio were influenced by nutrient levels, and net income continued to increase till the highest dose (125% RDF) tested in the study (` 23200.15 ha$^{-1}$), while the gross B: C ratio increased till 100% RDF (2.14). Economic assessment of data, based on current fertilizer price and crop value or minimum support price (MSP) scenario, ample NPK ($N_{100}P_{50}K_{50}$) treatment showed favorable return on investment for N (` 5.62), P (` 2.40) and K (` 3.52) fertilizers in new alluvial soil of West Bengal.

Key words: Sunflower, NPK levels, nutrient use efficiency, economics, yield

INTRODUCTION

Sunflower holds a great promise in meeting out the shortage of edible oils in India with higher yield potential and healthy oil quality. Because of its short duration life cycle, and photo and thermo-insensitivity, the crop has wider adaptability in different agro-climatic regions and soil types. India produces 1.44 million ton (mt) of total sunflower seed from an area of about 2.34 million ha (m ha), with an average productivity of 615 kg ha^{-1} (Shekhawat and Shivay, 2008). Since introduction of this crop in India during 1970s, productivity has remained low as compared to world average productivity though the area under this crop has increased markedly (Krishnamurthy *et al.*, 2011). Optimum resource use efficiency (RUE) is a prerequisite for sustainable production systems. A major driver for yield, especially in intensive agricultural systems, is fertilizer. Inappropriate use of fertilizers in sunflower, particularly excessive or ill-timed application, can lead to poor uptake, wasted valuable resources, and potential environmental damage (Hawkesford, 2012). Role of plant nutrients is of paramount importance, and balanced use of fertilizer could be one of the options to increase nutrient use efficiency (NUE). Nitrogen is the major nutrient that enhances the metabolic processes that lead to increase in vegetative, reproductive growth and yield of the crop. Furthermore, N fertilizer application affects dry matter production as well as N accumulation and partitioning into various parts of crop plants for the growth, development and other processes (Khaliq and Cheema, 2005). Phosphorus (P) deficiencies can limit the accumulation of crop biomass. Abbadi and Gerendas (2011) observed reduction in the rate of leaf expansion and photosynthetic rate per unit of leaf area of sunflower under P deficiencies. Application of K fertilizer was found to be particularly effective with respect to yield formation in sunflower (Amanullah and Khan, 2011). Sunflower, being deep-rooted crop, is very much responsive to nutrients. Study has reported that a sunflower crop yielding 1.8 t ha^{-1}of seed removes 88 kg N, 10 kg P and 54 kg K ha^{-1} (Shyamkiran, 2000). The effect of applied nutrients

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on yield attributes and yield has not yet been studied in the new alluvial soil of West Bengal, India. Therefore, understanding the response relationship between nutrients and sunflower yield is essential for its judicious management especially for the resource challenged small and marginal farmers of the region. Present study was conducted i) to determine the effect of nutrients on productivity of sunflower especially in the new alluvial soils of West Bengal, ii) to develop an apparent soil nutrient balance sheet considering the indigenous nutrient supplying capacity of the new alluvial soil of West Bengal, and finally iii) to assess economic return on investment in N, P and K fertilizers with an aim to provide guidance of nutrients to the resource challenged farmers of West Bengal.

MATERIALS AND METHODS

Replicated field experiment was conducted at Central Research Farm under Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India (23°26'N, 88°22'E with altitude of 12.0 m above the MSL).The sandy clay loam soil (64.8% sand, 10.4% silt and 24.8% clay) of the experimental field was neutral in reaction (pH 6.9) with adequate internal drainage. The experimental soil initially contained 8.9 g organic matter per kg soil, with 180.2 kg ha^{-1} available N (low), 36.1 kg ha^{-1} available P (high) and 153.4 kg ha^{-1} available K (medium).The treatments comprised of six NPK doses *viz.* T_1 :Farmer's fertilizer practice (FPP) ($N_{60}P_{30}K_{30}$), T_2 : State recommendation (SR) or 100% RDF ($N_{80}P_{40}K_{40}$), T_3 : 125% RDF ($N_{100}P_{50}K_{50}$),T_4 : 125% PK ($N_0P_{50}K_{50}$), T_5 : 125% NK ($N_{100}P_0K_{50}$) and T_6 : 125% NP ($N_{100}P_{50}K_0$), and were laid out in a randomized complete block design (RCBD) with four replications. Urea, single superphosphate (SSP), and muriate of potash (MOP) were used as a source of N, P and K, respectively. Half dose of N with full dose of P and K were applied as basal, rest 50% N was top-dressed at 30 days after sowing (DAS). The hybrid seed 'PAC 361' was sown on 19th January, 2013, by maintaining a spacing of 60cm × 30cm. The field was irrigated immediately after sowing. The crop was harvested when it attained physiological maturity as indicated by yellow color on the backside of the capitulum. At harvest, five plants were randomly selected in each treatment for recording growth and yield parameters. Post-harvest soil samples (0-15 cm depth) from each plot were collected, air-dried, ground, and passed through a 2 mm sieve. The available nitrogen was estimated through the hot alkaline permanganate method (Subbiah and Asija, 1956). The available phosphorus were extracted with 0.5 M $NaHCO_3$ (pH 8.5) and estimated through a UV-VIS spectrophotometer (Olsen *et al.*, 1954). Available fraction of potassium was extracted with neutral normal ammonium acetate (pH 7.0; 1:10 w/v) solution and estimated through a Flame photometer. Plant samples from each treatment were collected, oven dried, and ground for analyzing total recoveries of N, P and K at harvest. Nitrogen was estimated by the micro-Kjeldahl method. For determination of P and K content, material was digested in tri-acid (HNO_3 : H_2SO_4 : $HClO_4$ :: 10:1:4) (Jackson, 1973) and estimated by spectrophotometer and flame photometer, respectively. The economic parameters (cost of cultivation, gross return, net return and B: C ratio) were worked out on the basis of prevailing market prices of inputs and outputs. Nutrient balance sheet was estimated as per method given by Bochalia *et al.* (2011). Yield increase (nutrient response in kg/ha) and return on investment (ROI) was estimated using the following equations (Shahi *et al.*, 2012):

Nutrient response = Grain yield in ample NPK plot – grain yield in a nutrient omission plot

Return on investment (ROI) for a nutrient = yield increase due to the nutrient × minimum support price (MSP) of crop / applied nutrient cost

The growth and yield related characters of sunflower, nutrient (N, P, and K) uptake in plants and available nutrient (N, P and K) status of post-harvest soil were subjected to analysis of variance (ANOVA). Significance ($p \leq 0.05$) was tested using the Windows-based SPSS software (ver 18.0).

RESULTS AND DISCUSSION

Growth attributes

The experimental data revealed that the application of inorganic sources of nutrients in different combination induced marked variation in growth attributes of sunflower (Table 1). Ample NPK (125% RDF) recorded maximum plant height at 50 and 100 DAS, but was statistically at par with state recommendation (SR) i.e. 100% RDF; and both of them differed significantly from farmers' fertilizer practice (FPP). High NPK doses might have extended the growth period and thus increased plant height (Sadiq *et al.*, 2000). Siddiqui *et al.* (2009) also recorded tallest plant height and maximum stem girth under application of $N_{90}P_{45}K_{45}$ in sunflower cv. HO-1. Particularly higher P supply increased both shoot and root growth, but the former to a greater extent than the latter, and thereby plant height and dry matter increased. Cechin and Fumis (2004) also found that the sunflower height and shoot dry matter in better available N-grown plants were significantly higher compared to less available N-grown plants. Yadav *et* *al.* (2009) also registered maximum plant height and other growth attributes with 125% (RDF, 100: 50: 50 kg N, P_2O_5 and K_2O ha^{-1}, respectively). Longer stem possess more number of nodes, which in turn results in more number of leaves. The higher number of leaves is reflected in case of leaf area index (LAI) at all the crop growth period (Krishnamurthy *et al.*, 2011). In the present study, LAI was significantly affected by NPK rates, and achieved its maximum value with $N_{100}P_{50}K_{50}$ (Table 1). A minimum value for LAI was recorded in N-omitted plots ($N_0P_{50}K_{50}$) and it was significantly less compared to other treatments. Dry matter production (DMP) increased with time, after crop establishment and continued the whole crop cycle, until maturity in all the treatments. The maximum DMP was observed with 125% NPK ($N_{100}P_{50}K_{50}$), and significantly higher LAI for the same treatment might have contributed to higher net photosynthesizing area which facilitated higher rate of photosynthesis resulting in higher amount of DMP (Krishna Murthy *et al.*, 2011). The yield parameters of this treatment were statistically at par with 100% RDF while minimum DMP was recorded with zero-N plants (Table 1). Positive effect of N fertilizer on DMP has earlier been demonstrated by Nasim *et al.* (2011). The enhancement of DMP with increasing rate of NPK was due to better crop growth rate that gave more photosynthates, LAI, and ultimately produced more biological yield. This is in accordance with the study by Dordas and Sioulas (2009). Yadav *et al.* (2009) further opined that improvement in growth attributes under higher NPK level might have helped in better nutrient uptake by the crop which in turn resulted in assimilation of photosynthates towards sink as well as higher dry matter accumulation and favored the plant growth under 125% RDF.

Table 1: Effect of different treatment combinations of NPK fertilizers on growth attributes of sunflower

Treatment	Plant height (cm)		LAI		DMP (g $plant^{-1}$)	
	50 DAS	100 DAS	50 DAS	100 DAS	50 DAS	100 DAS
$N_{60}P_{30}K_{30}$	75.67^{a}	106.33^{ab}	1.16^{a}	1.13^{b}	47.04^{ab}	55.01^{a}
$N_{80}P_{40}K_{40}$	90.83^{ab}	117.83^{bc}	1.41^{ab}	1.40^{c}	63.11^{bc}	72.30^{a}
$N_{100}P_{50}K_{50}$	104.68^{b}	127.67^{c}	1.73^{b}	1.51^{c}	74.38^{c}	99.79^{b}
$N_0P_{50}K_{50}$	70.68^{a}	93.67^{a}	1.05^{a}	0.96^{a}	34.67^{a}	53.51^{a}
$N_{100}P_0K_{50}$	81.67^{a}	112.33^{abc}	1.17^{a}	1.14^{b}	44.03^{ab}	72.93^{a}
$N_{100}P_{50}K_0$	86.67^{ab}	113.33^{abc}	1.22^{a}	1.20^{b}	48.34^{ab}	78.42^{ab}

LAI, Leaf area index; DMP, Dry matter production; Values are means of four replicates.
Means followed by a different letter are significantly different at $p \leq 0.05$ by Duncan's multiple range test

The omission of N caused maximum reduction in growth attributes due to decreased leaf area, which in turn reduced photosynthetic activity (Abdel-Motagally and Osman, 2010). The magnitude of increase in growth attributes was higher for initial 50 days crops compared to later 50 days. Attributes such as plant height (48.1 and 36.3%), DMP (114.5 and 86.5%) and LAI (64.7 and 57.3%) were higher in ample NPK plots than N omission plot at 50 and 100 DAS. Phosphorus omitted plots exerted significant reduction in plant height (21.9 and 12.0%), DMP (40.8 and 26.1%) and LAI (32.4 and 24.5%) at 50 and 100 DAS, respectively when compared with ample NPK plots (Table 1). Extent of reduction of the above growth attributes was less in K omitted plots as compared to the N and P omitted plots (17.2 and 11.2% for plant height, 35.0 and 21.4% for DMP, and 29.5 and 20.5% for LAI at 50 and 100 DAS, respectively). Potassium omitted plots led to lower dry matter production, which might be due to growth-limiting K concentration in the leaf tissue. These results showed that N is the major driver for growth followed by P and K, and balanced fertilization always plays a vital role in plant growth and biomass production. The crop growth in N, P, and K omission plots was supported to some extent by the inherent soil fertility status (available N, P, and K content of initial soil). Since sunflower is an exhaustive crop (Bodake and Rana, 2009) and the experimental soil was low in N and medium in P and K content, NPK omitted plots are expected to show negative balance for all three primary nutrients in the post-harvest soil.

Yield attributes and yield

Nutrient omitted plots showed marked reduction in yield attributes such as seeds per capitulum, seed weight per capitulum, 100 seed weight, and seed yield (Table 2). Higher head diameter and number of seeds per capitulum is known to facilitate yield increase in sunflower (Krishnamurthy *et al.*, 2011; Nasim *et al.*, 2011). In the present study, sunflower hybrid produced higher seeds per capitulum with ample NPK plots (125%

Table 2: Effect of different treatment combinations of NPK fertilizers on yield attributes and yield of sunflower

Treatment	**No. of seeds capitulum^{-1}**	**Seed weight capitulum^{-1} (g)**	**100 seed weight (g)**	**Seed yield (kg ha^{-1})**
$N_{60}P_{30}K_{30}$	860.33^{ab}	44.19^{ab}	5.33^{ab}	1296.33^{a}
$N_{80}P_{40}K_{40}$	1000.33^{bc}	53.74^{c}	5.60^{bc}	1404.33^{b}
$N_{100}P_{50}K_{50}$	1129.33^{c}	64.41^{d}	5.73^{c}	1465.15^{b}
$N_{0}P_{50}K_{50}$	819.67^{a}	39.62^{a}	5.13^{a}	1221.00^{a}
$N_{100}P_{0}K_{50}$	830.00^{a}	41.19^{a}	5.21^{a}	1265.33^{a}
$N_{100}P_{50}K_{0}$	852.33^{ab}	52.16^{bc}	5.27^{a}	1289.00^{a}

Values are means of four replicates.
Means followed by a different letter are significantly different at $p \leq 0.05$ by Duncan's multiple range test

RDF), that was statistically at par with 100% RDF; while zero-N (125% PK) gave significantly less seeds. These results substantiate the findings of Rondanini *et al.* (2007) and Cantagallo *et al.* (2009), who also reported that the shortage of N affects the development and growth of both source and sink, and the number of seeds per capitulum. On an average, heavier seeds (considering 100 seed weight) was recorded from ample NPK plots (125% RDF), which was statistically at par with 100% RDF (Table 2). Farmer's fertilizer practice (FFP) exerted significantly low yield attributes and yield of sunflower when compared with 100 or 125% RDF. Effect of different treatments on seed yield was prominent. Mean higher seed yield was recorded in $N_{100}P_{50}K_{50}$ (ample NPK) treated plots and that was statistically at par with $N_{80}P_{40}K_{40}$ (100% RDF / SR). The minimum seed yield (1221 kg ha^{-1}) was observed in the N omission treatment (only 125% PK). Zubillaga *et al.* (2002) also obtained greater difference in yield of sunflower with N application under adequate soil water condition. Omission of nutrients from ample NPK treatment caused variable reduction in yield attributes and yield (Table 2). When compared with ample NPK plots, the magnitude of reduction due to N omission was to the tune of 27.4, 38.5, 10.5 and 16.7% for number of seeds per capitulum, seed weight per capitulum, 100 seed weight and seed yields, respectively. These results are in line with the work of FatihKilli (2004). Lesser extent of reduction was noticed in P (26.5, 36.1, 9.1 and 13.6% for number of seeds per capitulum, seed weight per capitulum, 100 seed weight and seed yields, respectively) and K omitted plots (24.5, 19.0, 8.0 and 12.0% for number of seeds per capitulum, seed weight per capitulum, 100 seed weight and seed yields, respectively).

Table 3: Nutrient uptake in sunflower and available nutrient status of post-harvest soil as influenced by different treatment combinations of NPK fertilizers

Treatment	**Nutrient uptake (kg ha^{-1})**			**Available nutrient status (kg ha^{-1})**		
	N	**P**	**K**	**N**	**P**	**K**
$N_{60}P_{30}K_{30}$	32.80^{a}	7.14^{a}	37.53^{ab}	138.24^{a}	34.42^{b}	58.77^{a}
$N_{80}P_{40}K_{40}$	49.46^{ab}	11.29^{bc}	57.12^{bc}	184.45^{cd}	42.47^{c}	75.19^{d}
$N_{100}P_{50}K_{50}$	68.75^{b}	14.47^{c}	79.12^{c}	167.72^{b}	50.19^{d}	70.88^{cd}
$N_{0}P_{50}K_{50}$	27.67^{a}	7.53^{ab}	30.19^{ab}	171.72^{bc}	47.88^{d}	73.96^{d}
$N_{100}P_{0}K_{50}$	42.20^{a}	5.67^{a}	37.27^{ab}	192.05^{d}	13.93^{a}	65.45^{bc}
$N_{100}P_{50}K_{0}$	36.28^{a}	9.64^{ab}	22.20^{a}	189.87^{d}	48.58^{d}	64.28^{b}

Values are means of four replicates.
Means followed by a different letter are significantly different at $p \leq 0.05$ by Duncan's multiple range test

The increase in soil nitrogen due to fertilization causes an increase in plant cells with greater number of leaves that led to increased yield components and yield per unit area. Higher seed yields with high rates of N were associated with an increase in seed number per capitulum, which ultimately leads to higher seed weight per capitulum. Higher seed yield of sunflower with increasing N rates is attributed to higher head diameter and seed weight (Abdel-Motagally and Osman, 2010). Phosphorus application produced greater and more consistent effects on crop performance as P fertilization allowed more efficient use of supplied N. The P application is believed to increase the N supply (soil + fertilizer) use efficiency in sunflower (Zubillaga *et al.*, 2002) and also to increase the photosynthetic rate. Potassium fertilizer plays many important roles in the plant physiological processes like transportation of solutes, stomatal movement, activation of enzymes, translocation of carbohydrates to the sink, and finally, improving the dry matter production(Abdel-Motagally and Osman, 2010).

Table 4: Balance sheet for N, P and K as computed after harvest of sunflower crop

Treatment	Initial soil nutrient status (a)	Nutrient added through fertilizer (b)	Total Nutrient (c = a + b)	Crop uptake (d)	Expected balance (e = c - d)	Actual balance (f)	Apparent gain/ loss g = (f-e)	Actual gain/ loss h = (f-a)
Nitrogen								
$N_{60}P_{30}K_{30}$	180.24	60	240.24	32.80	207.44	138.24	-69.19	-42.00
$N_{80}P_{40}K_{40}$	180.24	80	260.24	49.46	210.78	184.45	-26.33	4.21
$N_{100}P_{50}K_{50}$	180.24	100	280.24	68.75	211.49	167.72	-43.77	-12.52
$N_{0}P_{50}K_{50}$	180.24	0	180.24	27.67	152.57	171.72	19.15	-8.52
$N_{100}P_{0}K_{50}$	180.24	100	280.24	42.20	238.04	192.05	-45.99	11.81
$N_{100}P_{50}K_{0}$	180.24	100	280.24	36.28	243.96	189.87	-54.09	9.63
Phosphorus								
$N_{60}P_{30}K_{30}$	36.11	30	66.11	7.14	58.97	34.42	-24.56	-1.69
$N_{80}P_{40}K_{40}$	36.11	40	76.11	11.29	64.82	42.47	-22.35	6.36
$N_{100}P_{50}K_{50}$	36.11	50	86.11	14.47	71.64	50.19	-21.45	14.08
$N_{0}P_{50}K_{50}$	36.11	50	86.11	7.53	78.58	47.88	-30.70	11.77
$N_{100}P_{0}K_{50}$	36.11	0	36.11	5.67	30.44	13.93	-16.51	-22.18
$N_{100}P_{50}K_{0}$	36.11	50	86.11	9.64	76.47	48.58	-27.89	12.47
Potassium								
$N_{60}P_{30}K_{30}$	153.35	30	183.35	37.53	145.82	58.77	-87.05	-94.58
$N_{80}P_{40}K_{40}$	153.35	40	193.35	57.12	136.23	75.19	-61.04	-78.16
$N_{100}P_{50}K_{50}$	153.35	50	203.35	79.12	124.23	70.88	-53.35	-82.47
$N_{0}P_{50}K_{50}$	153.35	50	203.35	30.19	173.16	73.96	-99.20	-79.39
$N_{100}P_{0}K_{50}$	153.35	50	203.35	37.27	166.08	65.45	-100.63	-87.90
$N_{100}P_{50}K_{0}$	153.35	0	153.35	22.20	131.15	64.28	-66.88	-89.07

Nutrient uptake and nutrient balance

The increased uptake of major nutrients is primarily responsible for improved growth characters and yield attributes culminating into increased seed yield (Krishnamurthy *et al.*, 2011). Increasing levels of NPK application had positive influence on the total uptake of various nutrients by sunflower. The total N, P and K uptake was found maximum with 125% RDF which was statistically at par with 100% RDF, and superior to all other fertility treatments (Table 3). Increased total biomass with increasing nutrient application might be the reason for greater absorption of all the nutrients from the soil, resulted in higher total uptake of various nutrients (Yadav *et al.*, 2009). Bahl and Toor (1999) demonstrated that phosphorus uptake from the soil source was relatively higher in the non-calcareous soils that is similar to the soil type of the present study. Lowest uptake of N (27.67 kg ha^{-1}), P (5.67 kg ha^{-1}) and K (22.20 kg ha^{-1}) were observed with $N_{0}P_{50}K_{50}$, $N_{100}P_{0}K_{50}$ and $N_{100}P_{50}K_{0}$, respectively. Present study shows that nutrient status of the post-harvest soil was also influenced with various levels of NPK application. Available N, P, and K status of post-harvest soil was higher in plots receiving $N_{100}P_{0}K_{50}$, $N_{100}P_{50}K_{50}$ and $N_{80}P_{40}K_{40}$, respectively. Lower values of available N, and K were obtained with FFP ($N_{60}P_{30}K_{30}$) while for available P treatment $N_{100}P_{0}K_{50}$held responsible. There was apparent loss of N, P and K in all the plots under study (Table 4). Actual balance of N was positive in plots fertilized with $N_{80}P_{40}K_{40}$, $N_{100}P_{0}K_{50}$ and $N_{100}P_{50}K_{0}$. This could be attributed to the fact that there is a synergistic effect i.e. positive interaction between N and P, and N and K uptake (Zubillaga *et al.*, 2002). There was actual gain of P status of post-harvest soil in all the treatments, except FFP and P-

Table 5: Economic returns of sunflower cultivation

Treatment	Common cost of cultivation (` ha^{-1})	Treatment cost of cultivation (` ha^{-1})	Total cost of cultivation (`ha^{-1})	Gross return (` ha^{-1})	Net return (` ha^{-1})	B : C ratio
$N_{60}P_{30}K_{30}$	15450	3182.61	18632.61	38889.90	20257.29	2.09
$N_{80}P_{40}K_{40}$	15450	4243.48	19693.48	42129.90	22436.42	2.14
$N_{100}P_{50}K_{50}$	15450	5304.35	20754.35	43954.50	23200.15	2.12
$N_{0}P_{50}K_{50}$	15450	4000.00	19450.00	36630.00	17180.00	1.88
$N_{100}P_{0}K_{50}$	15450	2804.35	18254.35	37959.90	19705.55	2.08
$N_{100}P_{50}K_{0}$	15450	3804.35	19254.35	38670.00	19415.65	2.01

Cost of Urea: ` 6 $kg^{-1}$Single super phosphate (SSP): ` kg^{-1}; Muriate of potash (MOP):` $kg^{-1}$; Labour wages @ ` 167 $m.u.^{-1}$ Product cost: ` 30 kg^{-1} seed omitted plots. However, the actual balance of K was negative which means there was actual loss of K content in post-harvest soil, irrespective of treatments. This clearly explains that amount of K utilized by the sunflower crop was much higher than that of applied through fertilizer. Therefore a higher dose might be required for calculating the agronomic efficiency. Present study also shows that the correlations between seed yield and N uptake, seed yield and P uptake, and seed yield and K uptake were statistically significant (Fig. 1).

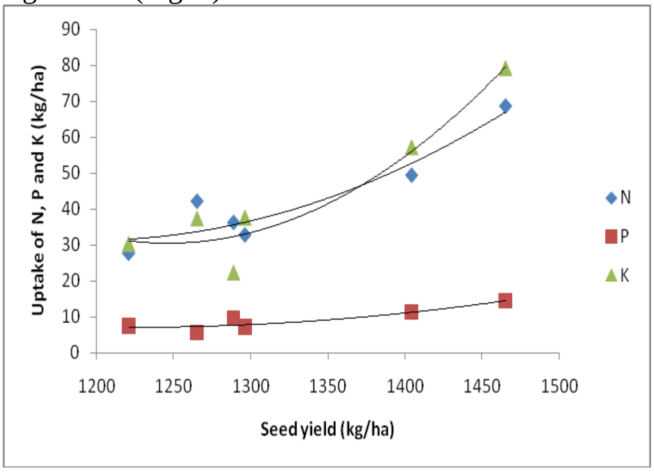

Fig. 1: Relationship of nutrient uptake with seed yield

Economics

Economics is the foremost consideration that finally decides the adoption of any recommended practice at farming situations, and whether an agronomic management plan should be technically and economically viable to be sustainable (Ramesha *et al.*, 2011). In the present study, net return and gross B:C ratio were influenced by nutrient levels (Table 5). Net income continued to increase till the highest dose tested in the study (125% RDF), and it was because of increased seed yield received at higher NPK application. The gross B:C ratio increased till 100% RDF and decreased a bit at 125% RDF. Lowest net return and B:C ratio was recorded with zero-N (125% PK), followed by zero-P (125% NK) and zero-K (125% NP). Economic assessments were determined based on the observed NPK response levels with current prices of these fertilizers and MSP of sunflower. It was observed that the ROI were higher than ` 2/- under all scenarios (Fig. 2). This indicates that NPK application at the rate of 80: 40: 40 kg N, P and K ha^{-1}, respectively in sunflower is economical at current price scenario, and farmer's profit can be assured when fertilizer application is guided by indigenous nutrient supply and expected nutrient response at a particular location.

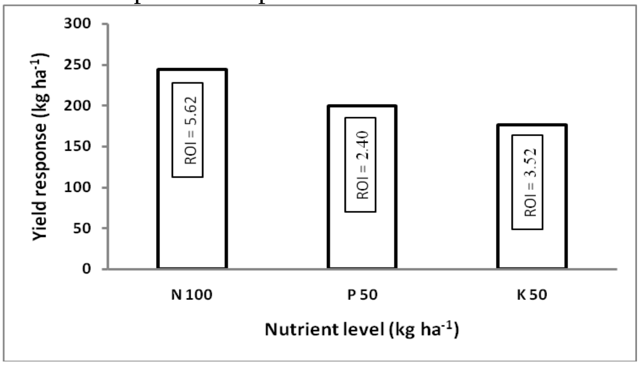

Fig. 2: Yield response to nutrients and return on investment (ROI) in sunflower cultivation

The present study clearly highlights the large variability observed in nutrient supplying capacity of sandy-loam soil of new alluvial zone of West Bengal. Average yield loss due to N omission was higher for sunflower grown in Indo-Gangetic plains (IGP) of West Bengal. The data again clearly show that most of the soils in the IGP have low K supply levels. Profit analysis revealed that N, P and K application in balanced proportion would be a profitable option for farmers.

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