The Bioscan 9(3): 1107-1112, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

NITROGEN AND PHOSPHORUS CONTENT AND UPTAKE, SOIL NUTRIENT BALANCE AND SOYBEAN PRODUCTIVITY UNDER DIFFERENT LEVELS AND SOURCES OF PHOSPHORUS AND PLANT GROWTH REGULATORS IN SUB HUMID RAJASTHAN

SHANKER LAL KHASWA[1], R. K. DUBEY[2], R. C. TIWARI[3], SHAILENDRA SINGH[4]*, BHAGWAN SINGH CHOUDHARY[5] AND INDU SINGH[6]
[1]Department of Agronomy,
MaharanaPratap University of Agriculture and Technology, Udaipur - 313 001 (Rajasthan), INDIA
[2]Agronomy, Central Soil and Water Conservation Research and Training Institute, Research Centre, Chhalesar, Agra - 282 006 (U. P.) INDIA
[3]Professor, Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur - 313 001 (Rajasthan) INDIA
[4]Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur - 313 001 (Rajasthan), INDIA
[5]Senior Branch Manager, Bank of India, Jaipur - 302 018 (Rajasthan) INDIA
[6]Assistant Agriculture Officer, Government of Rajasthan, Jaipur - 302 018 (Rajasthan) INDIA
e-mail: shailbhadawar@gmail.com

KEYWORDS
Nitrogen uptake
Phosphorus levels
Phosphorus source
Phosphorus uptake
Plant growth regulators
Soybean productivity

Received on :
23.11.2013

Accepted on :
10.07.2014

***Corresponding author**

ABSTRACT

An experiment was conducted at Udaipur during *kharif* seasons of 2009 and 2010 on soybean crop involving twenty seven treatments *i.e.* three levels (20, 30 and 40 kg P_2O_5 ha^{-1}) and three sources (Single super phosphate or SSP; phosphorus rich organic manure or PROM and di-ammonium phosphate or DAP) of phosphorus in main plots and three plant growth regulators or PGRs (water spray, benzyl adenine 50 ppm and NAA 100 ppm) in sub plots of a split plot design having three replications. Results revealed that 40 kg P_2O_5 ha^{-1}, SSP and NAA recorded significantly higher pooled grain and stover yield equivalent to 25.95 and 37.37; 25.12 and 36.23 and 24.23 and 35.73 q ha^{-1}than their respective counterparts, respectively. The enhancements in grain and stover yields were associated with significantly higher pooled nitrogen and phosphorus uptake (kg ha^{-1}) equivalent to 243.96 and 24.79; 228.10 and 24.52 and 229.90 and 23.44 under 40 kg P_2O_5 ha^{-1}, SSP and NAA, respectively. Significantly higher pooled available soil N (298.24 kg ha^{-1}) andP_2O_5 (25.99 kg ha^{-1}) was recorded under 40 kg P_2O_5 ha^{-1} but variations among different PGRs were indifferent. Significantly higher soil pooled soil N was recorded under PROM (294.93 kg ha^{-1}) but significantly higher pooled soil P_2O_5 was recorded under SSP (25.72 kg ha^{-1}).

INTRODUCTION

Soybean, a legume oilseed beset with excellent nutritional quality, is the third largest oilseed crop in India; however its productivity is far below the global average and demonstrated yields in the country. This can be ascribed to poor input management; larger concentration of oilseeds in less productive dry lands and rain-fed areas and a variety of other agronomical, physiological and genetic constraints (inadequate phosphorus nutrition, flower and bud drop, lack of synchronous flowering and maturity, improper dry matter partition etc.). Phosphorus doses and sources as well as plant growth regulators are known to enhance soybean productivity by virtue of optimizing different metabolic and physiological processes of plants, nutrition, growth and productivity (Franzen 2013; Deotale et *al*., 2011; Singh et *al*., 2001). In fact yield enhancements of oilseeds and pulses on fertilizer phosphorus applications directly relates to role of this mineral nutrients in photosynthesis regulations, root and shoot growth, nitrogen fixation, partitioning of photosynthates, quality parameters etc. However, inadequate phosphorus nutrition is one of the main and most common constraints behind poor soybean productivity in India. Indian soils are beset with high variability in crop response to varying doses and sources of inorganic phosphatic fertilizers in different agro-climates on account of wide variations in relative fixation of applied phosphatic material due to variations in soil pH, organic matter and calcium status and a complex chain of processes and factors that govern the ultimate crop phosphorus availability viz. clay content, C: P and C: N: P ratio, microbial immobilization, triggering of organic phosphorus mineralization on depletion of inorganic soil phosphorus, composition and solubility of fertilizer material, method of fertilization etc. Different levels and sources of chemical fertilizers may have different fate and worth on different sets of soils and agro-climate.

Clay loam soils of Udaipur are medium in available phosphorus but they are beset with high pH (> 8.0), organic carbon (about 0.69%) and calcium (about 3.53%) contents (quite conducive conditions for phosphorus precipitation). Increase in organic phosphorus decreases microbial phosphorus mineralization but C: P ratio of < 200 enhances organic phosphorus mineralization. Thus, application of inorganic P_2O_5 fertilizers may bring C: P ratio below 200 and induce organic phosphorus mineralization for variable periods depending upon rate of precipitation of applied phosphorus in to Ca-P complexes or immobilization otherwise. Thus, release of organic phosphorus can sharply decline or even stop beyond C: P ratio of 200.

PROM (a cheap, eco-friendly and water soluble source) has microbial ingredients (phosphorus solubilising bacteria and *Azotobactor*) potent to release organic acids to enhance native soil phosphorus mineralization while SSP contains 10-12% sulphur that can be of worth in lowering down the high soil pH in furrow slice for enhancement in available phosphorus on band placement beneath crop seeds. However, both these phosphorus sources have yet not been evaluated in soybean crop in this zone.

Combined use of phosphorus and PGRs sustainably enhance productivity of different crops through harmonizing different physiological and metabolic processes of plants (Howard *et al.*, 2001; Meena *et al.*, 2012). Use of PGRs may result in to improved photosynthesis and source to sink output, maintenance of optimum hormonal levels and protection against abiotic and biotic stress (Bajguz and Hayat, 2009). Applications of benzyl adenine (Kanojia and Sharma, 2008) and NAA (Deotale *et al.*, 2011) have significantly improved the growth, yield, yield attributes and quality of soybean. However, benzyl adenine or NAA and their interaction with different levels and sources of phosphorus have yet not been evaluated in soybean crop under Udaipur conditions specifically from point of view of crop uptake of nitrogen and phosphorus and soil balance of these nutrients for achieving sustainable agriculture. Therefore, this study aiming to achieve higher efficiency of applied phosphatic fertilizers was conducted and effect of different sources and levels of phosphorus and PGRs on crop uptake of nitrogen and phosphorus, yield performance of soybean crop and balance soil nutrients after soybean harvest was evaluated for higher sustained productivity in the zone.

MATERIALS AND METHODS

A two year field experiment was conducted at Instructional Farm of Rajasthan College of Agriculture, Udaipur which falls in agro-climatic zone IV a (Sub-Humid Southern Plains and Aravali Hills) during *kharif* seasons of2009 and 2010. The study site is located at 24°35′ N latitude and 72°42′ E longitude at an elevation of 582.17 m above mean sea level. Twenty seven treatments comprising of three levels (20, 30 and 40 kg $P_2O_5 ha^{-1}$) and three sources (SSP; PROM and DAP) of

Table 1: Effect of different phosphorus levels and sources and PGRs on N content and uptake in grain and stover of soybean crop in south Rajasthan.

Treatments	N content (%)						N uptake (kg ha^{-1})						Total N uptake (kg ha^{-1})		
	Seed			Stover			Seed			Stover					
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Phosphorus levels (kgP_2O_5 ha^{-1})															
20	6.26	6.29	6.27	1.56	1.57	1.57	115.70	117.07	116.39	42.95	44.43	43.69	158.65	161.50	160.08
30	6.58	6.64	6.61	1.68	1.70	1.69	146.08	149.39	147.73	55.24	58.22	56.73	201.32	207.61	204.46
40	6.82	6.85	6.84	1.75	1.78	1.76	171.76	183.96	177.86	64.60	67.59	66.10	236.37	251.55	243.96
S.Em ±	0.07	0.07	0.05	0.02	0.02	0.01	2.68	2.36	1.79	1.01	1.01	0.72	2.56	2.95	1.96
CD (P=0.05)	0.22	0.20	0.14	0.05	0.06	0.04	8.05	7.08	5.15	3.04	3.03	2.06	7.69	8.85	5.63
Phosphorus sources															
SSP	6.57	6.61	6.59	1.67	1.71	1.69	161.28	171.51	166.39	60.43	62.99	61.71	221.70	234.50	228.10
DAP	6.53	6.56	6.55	1.65	1.67	1.66	133.66	137.82	135.74	50.40	52.71	51.56	184.07	190.53	187.30
PROM	6.56	6.60	6.58	1.66	1.69	1.68	138.60	141.09	139.85	51.96	54.54	53.25	190.57	195.62	193.10
S.Em ±	0.07	0.07	0.05	0.02	0.02	0.01	2.68	2.36	1.79	1.01	1.01	0.72	2.56	2.95	1.96
CD (P=0.05)	NS	NS	NS	NS	NS	NS	8.05	7.08	5.15	3.04	3.03	2.06	7.69	8.85	5.63
Growth regulators															
Water spray (control)	6.22	6.30	6.26	1.59	1.60	1.60	123.82	129.40	126.61	46.93	48.81	47.87	170.76	178.21	174.48
Benzyl adenine 50 ppm	6.59	6.61	6.60	1.67	1.70	1.69	144.38	151.77	148.07	54.49	57.60	56.04	198.87	209.37	204.12
NAA 100 ppm	6.85	6.87	6.86	1.73	1.76	1.74	165.35	169.24	167.30	61.36	63.84	62.60	226.71	233.08	229.90
S.Em ±	0.07	0.06	0.05	0.01	0.02	0.01	2.26	2.28	1.61	0.89	0.99	0.67	2.49	2.78	1.87
CD (P=0.05)	0.21	0.17	0.13	0.04	0.05	0.03	6.48	6.54	4.52	2.56	2.83	1.88	7.14	7.98	5.26

phosphorus in main plots and three PGRs (water spray, benzyl adenine 50 ppm and NAA 100 ppm) in sub plots were evaluated in a split plot design having three replications. Foliar spray of designate concentration of PGRs was made twice at 30 and 65 days after sowing (DAS). Soil of study site was clay loam in texture with a slightly alkali pH (7.6), bulk density of 138 Mg/ m^3, calcium content of about 3.53%, organic carbon content of 0.69%, available nitrogen of 301.19 kg ha^{-1}, available phosphorus of 23.17 kg $P_2O_5 ha^{-1}$ and available potassium of 341.41 kg K_2O ha^{-1}. Soybean (cv. Pratap Soya 1) was sown 30 x 10 cm apart with the commencement of south west monsoon in last week of June to first week of July in a field that was under continuous cropping during both *rabi* and *kharif* seasons for last five years. Total rainfall received by soybean crop during *kharif* 2009 and 2010 was 425.20 and 758.0 mm, respectively. Soybean was raised applying recommended package of practces for the region. PROM contained 15.18% P_2O_5, 1.45% N, 1.12% K_2O and 0.4% S besides other micro-nutrients (Zn: 90 ppm; Cu: 32 PPM; Fe: 7920 ppm). Phosphatic fertilizers were applied through band placement below the seed before sowing. Nitrogen and phosphorus content in soil before sowing and after soybean harvest as well as content and uptake of nitrogen and phosphorus in seed and stover of soybean crop plants were analyzed for each experimental unit using standard methods. Variations in soil nitrogen and phosphorus status between different experimental units before soybean sowing were indifferent to each other; hence they have not been presented in this research article. Nitrogen and phosphorus in soil were analyzed following alkaline $KMnO_4$ method furnished by Subbiah and Asija (1956) and Olsen method (1954), respectively. Nitrogen and phosphorus in plant samples were analyzed using Nesseler's reagent colorimetric method given by Linder (1944) and ammonium vanadomolybdo-phosphoric acid yellow colour method as given by Richards (1968). Data were statistically analyzed for both the years and on pooled basis using standard procedure for analysis of variance (ANOVA) of split plot design.

RESULTS AND DISCUSSION

N content and uptake

Data (Table 1) revealed that each increment in the phosphorus level recorded significant enhancement in N content and uptake in seed and stover as well as total crop N uptake during 2009 and 2010 and on pooled basis. Application of 40 kg P_2O_5 ha^{-1} recorded 3.48, 9.09% and 4.14, 12.11% higher pooled N content in seed and stover that resulted in 20.41, 52.81% and 16.52, 51.29% higher pooled N uptake in seed and stover as well as 19.32 and 52.40% higher total pooled crop N uptake over 30 and 20 kg P_2O_5 ha^{-1}, respectively. This can be ascribed to higher vegetative growth at increasing phosphorus levels due to more root growth (higher root ramification and root occupied soil volume) and enhancement in symbiotic N fixation on account of increase in root nodules $plant^{-1}$ (Adelson and Marcelo, 2000; Singh *et al.*, 2001). Data further indicated that variations in N content in seed and stover under different phosphorus sources were indifferent; however N uptake in seed and stover as well as total crop N uptake recorded significant variations during 2009 and 2010 and on

Table 2: Effect of different phosphorus levels and sources and PGRs on phosphorus content and uptake in grain and stover of soybean crop in south Rajasthan

Treatments	Phosphorus content (%)						Phosphorus uptake (kg ha^{-1})						Total phosphorus uptake (kg ha^{-1})		
	Seed			Stover			Seed			Stover					
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Phosphorus levels (kg P_2O_5 ha^{-1})															
20	0.55	0.58	0.57	0.172	0.167	0.170	10.29	11.02	10.65	4.79	4.76	4.78	15.09	15.78	15.43
30	0.61	0.63	0.62	0.185	0.186	0.185	13.55	14.27	13.91	6.11	6.41	6.26	19.65	20.68	20.17
40	0.65	0.67	0.66	0.195	0.203	0.199	16.59	18.05	17.32	7.21	7.72	7.46	23.80	25.77	24.79
S.Em±	0.01	0.01	0.01	0.003	0.004	0.003	0.34	0.26	0.22	0.14	0.15	0.10	0.41	0.36	0.27
CD (P=0.05)	0.03	0.02	0.02	0.009	0.013	0.008	1.03	0.78	0.62	0.42	0.46	0.30	1.23	1.07	0.78
Phosphorus sources															
SSP	0.68	0.69	0.68	0.195	0.200	0.197	16.68	17.92	17.30	7.04	7.39	7.22	23.73	25.31	24.52
DAP	0.55	0.59	0.57	0.176	0.176	0.176	11.29	12.50	11.89	5.40	5.65	5.52	16.69	18.14	17.42
PROM	0.59	0.60	0.59	0.180	0.180	0.180	12.46	12.93	12.69	5.66	5.85	5.76	18.12	18.78	18.45
S.Em±	0.01	0.01	0.01	0.003	0.004	0.003	0.34	0.26	0.22	0.14	0.15	0.10	0.41	0.36	0.27
CD (P=0.05)	0.03	0.02	0.02	0.009	0.013	0.008	1.03	0.78	0.62	0.42	0.46	0.30	1.23	1.07	0.78
Growth regulators															
Water spray (control)	0.55	0.57	0.56	0.169	0.168	0.168	11.02	11.87	11.44	5.00	5.15	5.07	16.02	17.02	16.52
Benzyl adenine 50 ppm	0.61	0.64	0.62	0.186	0.189	0.188	13.57	14.76	14.16	6.10	6.43	6.27	19.67	21.19	20.43
NAA 100 ppm	0.65	0.67	0.66	0.196	0.200	0.198	15.85	16.71	16.28	7.01	7.31	7.16	22.85	24.02	23.44
S.Em±	0.01	0.01	0.00	0.003	0.003	0.002	0.21	0.23	0.16	0.11	0.12	0.05	0.25	0.29	0.19
CD (P=0.05)	0.02	0.02	0.01	0.007	0.008	0.005	0.61	0.67	0.44	0.32	0.36	0.24	0.71	0.84	0.54

pooled basis that was in an order SSP> PROM> DAP. SSP recorded 18.98 and 22.58%; 15.89 and 19.69% and 18.13 and 21.78% higher pooled N uptake in soybean seed and stover and total pooled crop N uptake than PROM and DAP, respectively. This can be ascribed to pH ameliorating effect of 10-12% sulfur traces contained in SSP that exerted a favorable effect on soil phosphorus supply to soybean plants in root zone (in and around furrow slice) on band placement of fertilizer below seed. Besides, independent favorable effect of sulfur on plant growth can also not be denied. Higher crop N uptake under PROM over DAP can be ascribed to more soil N availability on account of biological N fixation by *Azotobactor* contained in the former material. Different PGRs recorded significant variations in N content and uptake in seed and stover and total crop N uptake during 2009, 2010 and on pooled basis that was in order of NAA> benzyl adenine> water spray. The extent of increase in pooled N content and uptake in seed and stover and total crop N uptake under NAA was 3.94, 9.58% and 2.96, 8.75%; 12.99, 32.14 and 11.71, 30.77% and 12.63 and 31.76% over benzyl adenine and water spray, respectively. This reveals the superiority of auxinic NAA over cytokinin (benzyl adenine) in enhancing N uptake by soybean plants which can be attributed due to roles of PGRs under reference.

Phosphorus content and uptake

Each increment in phosphorus level recorded significantly higher phosphorus content and uptake in seed and stover as well as total phosphorus uptake by soybean crop during 2009, 2010 and on pooled basis. The extent of enhancement in pooled phosphorus content in seed and stover of soybean at phosphorus level of 40 kg P_2O_5 ha^{-1}corresponded to 6.45, 15.79% and 7.57, 17.06% over 30 and 20 kg P_2O_5 ha^{-1}, respectively. Similarly, increase in pooled phosphorus uptake in seed and stover of soybean at 40 kg P_2O_5 ha^{-1} was equivalent to 3.41, 6.67 and 1.21, 2.68 kg ha^{-1}over 30 and 20 kg P_2O_5 ha^{-1}, respectively. Thus, total phosphorus uptake by soybean crop at 40 kg P_2O_5 ha^{-1} was higher by 4.62 and 9.63 kg ha^{-1} than 30 and 20 kg P_2O_5 ha^{-1}, respectively. These findings corroborate with findings of many workers including Thakur and Girothia (2010). Supplementing phosphorus to soybean crop through SSP also recorded significantly higher phosphorus content and uptake in seed and stover as well as total phosphorus uptake by soybean crop than DAP and PROM during both the years and on pooled basis. However, variations in pooled phosphorus content in grain and stover of soybean due to DAP and PROM were indifferent. SSP recorded 19.30, 15.25% and 11.93, 9.44% higher pooled phosphorus content in grain and stover of soybean than DAP and PROM, respectively. This resulted in significantly higher pooled phosphorus uptake in grain and stover of soybean as well as total pooled phosphorus uptake by soybean crop on supplementing phosphorus through SSP which was equivalent to 5.81, 4.61; 1.70, 1.46 and 7.10, 6.07 kg ha^{-1} over DAP and PROM, respectively. This clearly establishes that sulfur traces in SSP mitigated precipitation of available phosphorus (soil solution phosphorus) in furrow slice of clay loam soils of Udaipur on band placement below soybean seeds that resulted in significantly higher crop uptake of phosphorus and led to enhanced phosphorus content and uptake in grain and stover over DAP and PROM. Different PGRs recorded significant variations in phosphorus content and uptake in grain and stover as well as total crop phosphorus uptake during both the years and on pooled basis that was in order of NAA> benzyl adenine> water spray. Foliar spray of NAA recorded 6.45, 17.86% and 5.32, 17.86% higher pooled phosphorus content in grain and stover which resulted in 14.97, 42.31 and 14.19, 41.22% higher phosphorus uptake in grain and stover as well as 14.73 and 41.89% higher total crop phosphorus mining than benzyl adenine and water spray, respectively. This revealed that PGRs activated (optimized) certain physiological and metabolic processes of soybean plants that resulted in significantly higher phosphorus content and uptakes over water spray. Data (Table 2) further revealed that overall impact of key role of cytokinin group benzyl adenine (cell division, improvement in morphological characters and total chlorophyll etc.) was less prompt than the auxinic NAA (cell elongation; cell wall biosynthesis; xylem differentiation; mRNA synthesis, improvement in leaf area, leaf area index and total chlorophyll etc.) so far as effect of PGRs on phosphorus content and uptake in soybean plants is concerned. Results on higher crop phosphorus uptake on application of NAA and benzyl adenine in soybean crop or other legumes are well supported by many workers including Kanojia and Sharma (2008), Deotale *et al.* (2011) and Rahdari and Sharizadeh (2012).

Available soil N and phosphorus after soybean harvest

Each increment in phosphorus level significantly enhanced the available soil N and phosphorus after harvest of soybean crop during both the years and on pooled basis (Table 3). Application of 40 kg P_2O_5 ha^{-1} recorded 13.40 and 28.72 kg ha^{-1} higher pooled available soil N as well as 1.21 and 2.58 kg ha^{-1} higher pooled available soil phosphorus than 30 and 20 kg P_2O_5 ha^{-1}, respectively. Higher available soil N after soybean harvest at 40 kg P_2O_5 ha^{-1}can be attributed due to more symbiotic N fixation at higher phosphorus levels on account of more nodules plant^{-1} and nodule weight plant^{-1} (Adelson and Marcelo, 2000; Singh *et al.,* 2001; Sharma *et al.,* 2002) while higher available soil phosphorus at each incremental phosphorus level clearly showed the increasing residual effect. Among different phosphorus sources, PROM recorded significantly higher pooled available N while SSP recorded significantly higher pooled available phosphorus after soybean harvest. PROM recorded 13.24 and 18.96 kg ha^{-1} higher pooled N in soil over DAP and SSP while SSP recorded 1.41 and 1.57kg ha^{-1} higher pooled soil phosphorus than PROM and DAP after soybean harvest, respectively. Significantly higher pooled available N under PROM can be ascribed to role of *Azotobactor* contained in this manure while significantly higher pooled available soil phosphorus under SSP can be attributed to 10-12% sulfur traces contained in it which mobilized native soil phosphorus in clay loam soils of Udaipur. Data revealed that different PGRs failed to record significant variation in the pooled soil N or phosphorus after harvest of soybean crop.

Yield performance of soybean

Each incremental phosphorus level, SSP and NAA recorded significantly higher grain and stover yield of soybean than their respective counterparts during both the years and on

Table 3: Effect of different phosphorus levels and sources and PGRs on available soil N and phosphorus (kg ha^{-1}) after harvest of soybean crop as well as on grain and stover yield

Treatments	Available soil N after soybean harvest (kg ha^{-1})			Available soil phosphorus after soybean harvest (kg ha^{-1})			Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Phosphorus levels (kg P_2O_5 ha^{-1})												
20	268.74	270.30	269.52	23.41	23.41	23.41	18.38	18.61	18.50	27.51	28.14	27.82
30	284.92	284.75	284.84	24.63	24.92	24.78	22.13	22.44	22.29	32.80	34.03	33.41
40	297.37	299.10	298.24	25.73	26.26	25.99	25.10	26.79	25.95	36.84	37.84	37.34
S.Em ±	3.94	3.92	2.78	0.34	0.44	0.28	0.28	0.31	0.21	0.49	0.49	0.34
CD (P=0.05)	11.80	11.76	8.01	1.03	1.31	0.80	0.85	0.94	0.61	1.46	1.46	0.99
Phosphorus sources												
SSP	275.71	276.24	275.97	25.36	26.09	25.72	24.45	25.79	25.12	35.87	36.60	36.23
DAP	281.20	282.17	281.69	24.13	24.17	24.15	20.31	20.81	20.56	30.22	31.49	30.86
PROM	294.11	295.74	294.93	24.28	24.33	24.31	20.86	21.24	21.05	31.05	31.91	31.48
S.Em ±	3.94	3.92	2.78	0.34	0.44	0.28	0.28	0.31	0.21	0.49	0.49	0.34
CD (P=0.05)	11.80	11.76	8.01	1.03	1.31	0.80	0.85	0.94	0.61	1.46	1.46	0.99
Growth regulators												
Water spray (control)	281.19	281.77	281.48	24.32	24.46	24.39	19.78	20.47	20.13	29.36	30.30	29.83
Benzyl adenine 50 ppm	283.99	285.29	284.64	24.64	24.93	24.79	21.80	22.84	22.32	32.43	33.61	33.02
NAA 100 ppm	285.84	287.09	286.47	24.81	25.19	25.00	24.04	24.54	24.23	35.36	36.10	35.73
S.Em ±	3.04	3.42	2.29	0.33	0.36	0.24	0.26	0.30	0.20	0.41	0.46	0.31
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.74	0.86	0.56	1.18	1.32	0.87

pooled basis (Table 3). This can be ascribed to considerably higher crop nitrogen and phosphorus uptake under these treatments. Application of 40 kg P_2O_5 ha^{-1} recorded 16.42 and 40.27% higher pooled grain and 11.76 and 34.22% higher pooled stover yield than 30 and 20kg P_2O_5 ha^{-1}, respectively. This yield enhancement was linked with higher pooled uptake of N and $P_2O_5$to a tune of 39.49, 83.16 and 4.62, 9.36 kg ha^{-1}at 40 kg P_2O_5 ha^{-1}over the phosphorus levels of 30 and 20 kg P_2O_5 ha^{-1}, respectively. Similarly, an enhancement of 4.56 and 4.07 q ha^{-1} in pooled grain yield as well as 5.37 and 4.75 q ha^{-1} in pooled stover yield under SSP was linked with higher pooled uptake of N and $P_2O_5$by 40.8, 35.0 and 7.10, 6.07 kg ha^{-1} over DAP and PROM, respectively. However, pooled grain (0.49 q ha^{-1}) and stover (0.42 q ha^{-1}) yields under DAP and PROM were indifferent on account of mild variations in uptake of N (5.8 kg ha^{-1}) and P_2O_5 (1.03 kg ha^{-1}). NAA recorded 8.56 and 20.37% higher pooled grain as well as 8.21 and 19.78% higher pooled stover yield than benzyl adenine and water spray which was linked with higher pooled uptake of N and $P_2O_5$by 25.78, 55.41 and 3.01, 6.92 kg ha^{-1}, respectively. Benzyl adenine also recorded significantly higher yield performance of grain (2.19 q ha^{-1}) and stover (3.19 q ha^{-1}) than water spray which was linked with higher pooled uptake of N and $P_2O_5$by 29.63 and 3.91 kg ha^{-1}, respectively. These results corroborate with findings of Kanojia and Sharma (2008) and Brar *et al.* (2010) on various levels of phosphorus; with Chavan *et al.* (2008) on different sources of phosphorus and with Kanojia and Sharma (2008), Deotale *et al.* (2011) and Rahdari and Sharizadeh (2012) on effect of foliar spray of NAA and benzyl adenine in soybean crop or other legumes. Significant effect of PGRs on source and sink strength and dry matter partitioning in groundnut is also reported by Sharma *et al*. (2013) and these twin factors stand to be key in crop yield formation. Besides, favourable influence of PGRs on contents of chlorophyll, leg-haemoglobin and nitrate reductase that significantly enhanced groundnut productivity is documented by Sharma and Sardana (2012).

REFERENCES

Adelson Paulo, A. and Marcelo Grandi, T. 2000. Ontogenic variations on absorption and utilization of phosphorus in common bean cultivars under biological nitrogen fixation. *Plant and Soil.* **225**: 1-10.

Bajguz, A. and Hayat, Shamsul 2009. Effect of brassinosteroids on the plant response to the environmental stresses. *Plant Physiol. Bioch.* **47**: 1-8.

Brar, B. S., Singh, J. and Benipal, D. 2010. Response of soybean to different levels of phosphorus and sulphur in alluvial soils of Punjab. *Indian J. Ecology.* **37**: 56-59.

Chavan, P. G., Shinde, V. S., Kote, G. M., Solunke, P. S. and Bhondve, A. A. 2008. Response of sources and levels of phosphorus with and without PBS inoculation on growth, yield and quality of soybean. *Res. on Crops.* **9**: 286-289.

Deotale, R. D., Kalamkar, V. B. and Banginwar, A. D. 2011. Effect of foliar sprays of cow urine and NAA on morpho-physiological, chemical, biochemical parameters and yield of soybean. *J. Soils and Crops.* **21**: 2 332-337.

Franzen, D. W. 2013. Soybean soil fertility. NDSU Agricultural Extension services no. SF1164.

**Hegde, D. M., SudhakarBabu, S. N., Rana, D. S. and Vyas, A. K.

2012. Agronomic research on oilseeds in India: An overview. *Indian J. Agron.* **57(3rd IAC special issue):** 58-62.

Howard Donald, D., Gwathmey, C. O., Lessman, G. H. and Robert, K. R. 2001. Fertilizer additives rates and plant growth regulators: Effect on cotton. *The J. Cotton Sci.* **5:** 42-52.

Kanojia, Y. and Sharma, D. D. 2008. Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L.) Merrill]. *Legume Res.* **31**: 51-53.

Linder, R. C. 1944. Rapid analysis methods of some or more common inorganic substance of plant and soil. *Plant physiol.* **19**: 76-84.

Meena, M. K., Chetti, M. B., Naik, D. Saida and Nawallagatii, C. M. 2012. Role of plant growth regulators in agriculture: A review on morpho-physiological, quality and yield parameters of crops. *Res. J. Agri. Sci.* **3(2):** 21-32.

Olsen, S. R., Cole, C. S., Watanable, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA, Washington, D.C., Circ. No. 939.

Rahdari, P. and Sharifzadeh, V. 2012. Effects of Auxin andCytokinin on morphological and physiological factors in Soybean (*Glycine max* L.). *Life Sci. J.* **9(4):** 5796-5807.

Richards, L. A. 1968. Diagnosis and improvement of saline and alkali soils. *USDA Handbook NO. 60*, Oxford and IBH Publishing Co., New Delhi.

Sharma, P. and Sardana, V. 2012. Effect of growth regulating substances on the chlorophyll, nitrate reductase, leghaemoglobin content and yield in groundnut (*arachis hypogaea*). *The Bioscan.* **7(1):** 13-17.

Sharma, P., Sardana, V. and Kandhola, S. S. 2012. Dry matter partitioning and source-sink relationship as influenced by foliar sprays in groundnut. The Bioscan. **8(4):** 1171-1176.

Sharma, S. C., Vyas, A. K. and Shaktawat, M. S. 2002. Effects of levels and sources of phosphorus under the influence of farm yard manure on growth determinations and productivity of soybean [*Glycine max* (L.) Merrill]. *Indian J. Agri. Res.* **36**: 31-37.

Singh, P. N., Singh, J. R. and Jeena, A. S. 2001. Physiological study of nitrogen and phosphorus application in soybean. *Legume Res.* **24**: 200-202.

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Sci.* **25**: 259-260.

Thakur, H. S. and Girothia, O. P. 2010. Response of soybean [*Glycine max* (L.)] and chick pea (*Cicer arietinum*) cropping sequence to phosphorus nutrition. *Soybean Res.* **8**: 13-19.