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Some improvement strategies for the sustainable chickpea development: Single or combined application of monosodium phosphate and sodium sulphate with or without gibberellic acid treatment by foliar or seed priming

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ABSTRACT

An experiment was laid out with a target to enhance the performance of gram by the foliar spray of a minute amount of monosodium phosphate and/or sodium sulphate (P and S each at 2 kg/ha were sprayed in two equal splits, i.e. half at 60 and the remaining half at the 70 DAS alone or in combination with the gibberellic acid (GA_3) treatment i.e., spray or soaking or P and S solution at 0.1%) with or without the seed priming of GA_3 (10^{-6}M GA_3 for 8h) and/ or the GA_3 foliar application (10^{-6}M GA_3 at 60-70 DAS). Monosodium phosphate and sodium sulphate each at 2 kg/ha were foliage applied in two equal splits, i.e. half at 60 and the remaining half at the 70 DAS alone or in combination with the GA_3. Prior to sowing, total seeds were categorised into two groups; one group of seeds was primed in 0.0M GA_3 and the other was primed in 10^{-6}M GA_3 aqueous solution, each for 8 hours. Total 16 treatments with 10 best combinations of monosodium phosphate and/or sodium sulphate with GA_3 are possible *viz*., F_{PS}, $S_{GA} + F_P$, $S_{GA} + F_S$, $S_{GA} + F_{PS}$, F_{GAP}, F_{GAS}, F_{GAPS}, $S_{GA} + F_{GAP}$, $S_{GA} + F_{GAS}$ and $S_{GA} + F_{GAPS}$. The combined application of monosodium phosphate and sodium sulphate with GA_3 stimulated seed yield per plant, total protein and carbohydrate content at 130 DAS, along with other parameters at the 80 and 90 DAS.

Key words: Carbonic anhydrase, Chickpea, Gibberellins, Photosynthesis, Yield.

INTRODUCTION

Though production of pulses in the recent decade has enhanced but is not in pace with the increase in population. Pulses for being a major source of protein and carbohydrate in Indian diet and for being resource conserving and environmental friendly, the increase in pulse production will act as a panacea for problems like nutritional security and deficiency disorders (Mazid, 2014a). Eleven primary pulses have been recognized by the Food and Agriculture Organization (FAO) of the United Nations at global level. These pulses include dry beans, lima bean, tepary bean, scarlet runner bean, black gram, green gram, moth bean, rice bean, dry broad bean, dry peas dry cowpea, pigeon pea, chickpea, lentil, bambara groundnut, lupines, common vetch and minor pulses (lablab, jack beans, sword bean, winged bean, velvet bean, and yam bean). Among pulses, for production, chickpea occupies the first position in India and third position at global level (FAO, 2012).

Among pulses, for production, chickpea occupies the first position in India and third position at global level (FAO, 2012). This crop is grown on 8.21 million hectares of our country with the annual production of 7.48 million tonnes and average productivity of 911 kg/ha (FAO, 2012). There has not been remarkable increase in area and productivity as witnessed in other commodities over the years. There have been a number of technological breakthroughs with promise to raise the productivity levels. Due to high pressure for cereals, nothing can be done to bring more land under cultivation. Farmers have a wrong notion that chickpea being a legume crop, does not need any nutrition and usually grow it on the marginal lands, without applying any fertilizer. The only alternative is to increase per hectare productivity. GA_3, P and S are known to play a positive role in regulating flower drop, premature pods development, and enhancing yield potential in plants. The rainfed crop records low biomass production due to inadequate soil moisture and nutrient availability ultimately resulting in less yields (Mazid and Mohammad, 2012; Khan *et al.,* 2011a).

Among the nutrients, P has been found to be the life-limiting element in natural ecosystems because it is often bound in highly insoluble compounds and hence, it becomes unavailable for plant uptake or utilization. Similarly, S is one of the limiting plant nutrients threatening the sustainability of production. S as a fertilizer or as a constituent of other fertilizers is generally not applied by farmers (Ganeshamurthy and Saha, 1999). However,

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combined application of P and S may have synergistic or antagonistic effects on yield, depending upon initial fertility status of soil; level of nutrients applied and crop type. Next to nutrients, GA_3 have significant role in the regulation of flowering and considered to be the most florigenic of known PGRs (Naqvi *et al.,* 2014). Considering the overwhelming importance of *Cicer arietinum* L., an experiment was laid out to test whether the spray of P and /or S in the presence or absence of GA_3 will improve the performance of chickpea.

MATERIALS AND METHODS

Aligarh is one of the seventy five districts of Uttar Pradesh. Authentic seeds of KWR-108 were obtained from the IIPR (Indian Institute of Pulse Research and Development), Kanpur. The seeds were soaked with DDW (double distilled water) for 2 h and then were surface sterilized with absolute ethyl alcohol followed by repeated washing with DDW. Prior to the foliar treatments, 100 millilitre (ml) stock solutions of GA_3 at 10^{-3}M were prepared. P and S solution at 0.1% was used for foliar spray. P and S each at 2 kg/ha were sprayed in two equal splits, i.e. half at 60 and the remaining half at the 70 DAS alone or in combination with the GA_3 treatment. The sources of P and S were sodium dihydrogen-orthophosphate and sodium sulphate respectively. These were in all 16 treatments with four replicates. For application of nutrients alone, DDW was used as solvent however, the hormone solution treated as solvent when nutrients and hormone applied together. The crop was sown on the 15th October, 2013 and harvested on the 20th March, 2014.

Sampling methods: Length of shoot on per plant basis was determined separately with the help of a metre scale. The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967) and it was expressed as g dm^{-2}.

$$SLW = \frac{\text{Leaf dry wight(g)}}{\text{Leaf area(dm 2)}}$$

The number of branches per plant were counted at regular intervals and mean values of four plants were expressed as number per plant. Total number of green leaves was estimated by counting the individual leaves from top to bottom of the plant and the mean value of plants selected at random in each treatment was expressed as number per plant. The shoot and root of each plant were dried in a hot air oven at 80^0C for 24 h and their dry weight was obtained separately with the help of an electronic balance. Then, total dry matter was calculated by adding the dry weights of different plant parts and expressed as grams per plant. LAI is the ratio of foliage area to ground area.

The P_N was measured in fully expanded leaves of somewhat the same age in all replicates by using the Infra Red Gas Analizer (IRGA), LICOR-6400, Nebraska, U.S. A). *Tr* was also measured by the IRGA simultaneously with P_N. The N-content in nodule was estimated by methodology described by Sadasivam and Manickam (2008). The Chl content was estimated in fresh leaves collected randomly from each replicate by the method of Arnon (1949). The NRA in fresh leaves was estimated by the method of Jaworski (1971). N-ase activity in fresh leaves was estimated by the acetylene reduction assays method of Turner and Gibson (1980). The seeds were utilized for assessing the other characteristics. The total seeds of two plants were threshed, cleaned and allowed to dry in the sun for some time and their weight was obtained with the help of an electronic balance, with expressing their weight on per plant basis. The seed protein and carbohydrate content in the dry seeds was estimated by adopting the methodology of Lowry *et al.* (1951) and Agrawal *et al.* (1994).

Statistical analysis: All data were analysed statistically adopting the analysis of variance technique, according to Gomez and Gomez (1984). In applying the F test, the error due to replicates was also determined. When 'F' value was found to be significant at 5% level of probability, least significant difference (LSD) was calculated.

RESULTS AND DISCUSSION

The effect of treatments was found significant on all growth characters studied at 80 and 90 DAS. Among treatments, combination of pre-sowing seed treatment with GA_3 and foliar spray of GA, P and S ($S_{GA}+ F_{GAPS}$) gave the maximum value of shoot length per plant at both sampling stages. Its effect was, however, equal to that of $S_{GA}+ F_{GAS}$ at each sampling stage. Treatment $S_{GA}+ F_{GAPS}$ gave 86.71 and 78.95% higher value at 80 and 90 DAS respectively than control, i.e. F_W. Treatment $S_{GA}+ F_{GAPS}$ gave the maximum of LAI value at both sampling stages. Its effect was followed by that of $S_{GA}+ F_{GAP}$ and $S_{GA}+ F_{GAS}$ at each stage of sampling and also by that of $S_{GA}+ F_{GA}$ at 90 DAS. Treatment $S_{GA}+ F_{GAPS}$ gave 218.42 and 186.21% higher value at 80 and 90 DAS respectively than F_W. All parameters of growth analysis viz., number of branches per plant, leaves dry weight per plant, total dry matter and its translocation and specific leaves weight are reported as non-significant at both stages (Table 1).

Treatment $S_{GA}+ F_{GAPS}$ gave the maximum value of NRA at each sampling stage. Its effect was, however, equalled by that of $S_{GA}+ F_{PS}$, F_{GAPS}, $S_{GA}+ F_{GAS}$ at both stages and was also by that of $S_{GA}+ F_S$ at 90 DAS. Treatment $S_{GA}+ F_{GAPS}$ gave 22.37 and 22.46 % higher value at 80 and 90 DAS respectively than F_W. Treatment $S_{GA}+ F_{GAPS}$ gave the maximum value of Chl content at both sampling stages. Its effect was, however, equal to that of $S_{GA}+ F_{GAP}$, $S_{GA}+ F_{GAS}$, $S_{GA}+ F_{GA}$, F_{GAS} and F_{GAP} at each stage of sampling and also to that of F_{GA} at 90 DAS. Treatment $S_{GA}+ F_{GAPS}$ gave 46.16 and 48.84% higher value at 80 and 90 DAS respectively than F_W. Among the treatments, water treatment proved best for nodule nitrate content at both stages. At 80 DAS, treatment $S_{GA}+ F_{GAPS}$ gave the maximum value of P_N and its

Table 1: Effect of gibberellic acid, P and S on yield and component traits of chickpea at two sampling stages (80 and 90 DAS)

Treatment	Shoot length per plant (cm)		Leaf area index (cm)		Number of branches		Leaves dry weight (g/plant)		Total dry matterSpecific production (TDM)		leaf weight (g dm^{-2})	
	80 DAS	90 DAS	80 DAS	90 DAS	80 DAS	90 DAS	80 DAS	90 DAS	80 DAS	90 DAS	80 DAS	90 DAS
F_W	36.10	38.00	15.20	17.40	19.44	16.78	2.48	3.67	16.10	17.30	0.63	0.65
F_P	38.70	40.00	16.90	17.90	16.73	17.78	3.78	3.89	17.90	17.00	0.76	0.67
F_S	39.20	40.00	23.20	24.10	20.75	17.85	4.67	4.75	18.30	16.60	0.54	0.66
F_{PS}	42.60	43.70	26.80	27.00	21.78	19.87	5.65	5.90	19.00	18.50	0.79	0.77
S_{GA}	40.30	42.10	28.70	31.20	18.70	18.65	4.89	4.80	18.90	16.70	0.65	0.72
$S_{GA}+F_P$	41.60	47.00	31.40	33.40	19.76	16.87	5.23	5.00	19.00	17.40	0.62	0.90
$S_{GA}+F_S$	45.80	47.20	30.90	35.20	20.79	18.00	5.34	5.56	21.10	17.50	0.78	0.56
$S_{GA}+F_{PS}$	47.20	48.80	37.10	39.40	21.00	21.84	6.00	6.90	22.00	18.00	0.99	0.94
F_{GA}	46.40	48.40	29.00	29.20	18.89	17.90	6.34	5.80	20.30	17.80	0.68	0.87
F_{GAP}	49.80	51.20	32.30	34.00	19.00	20.76	6.78	5.90	21.20	17.40	0.85	0.76
F_{GAS}	52.10	55.80	31.70	35.70	20.76	21.83	5.70	6.00	22.80	19.70	0.76	0.75
F_{GAPS}	54.80	56.10	36.50	40.00	21.67	22.78	6.87	6.40	23.56	20.30	0.74	0.84
$S_{GA}+F_{GA}$	54.20	61.20	41.20	41.40	22.78	21.65	7.00	6.80	22.00	21.65	0.89	0.78
$S_{GA}+F_{GAP}$	59.70	61.20	43.20	44.80	21.90	22.78	6.24	7.10	23.10	23.60	0.68	0.86
$S_{GA}+F_{GAS}$	65.20	67.00	42.00	45.70	22.00	23.89	6.67	7.60	23.50	23.58	0.98	1.00
$S_{GA}+F_{GAPS}$	67.40	68.00	48.40	49.80	24.64	24.65	7.90	8.70	24.60	25.69	1.17	1.18
C.D. at 5%	**3.47**	**3.58**	**2.28**	**2.41**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

effect was however, at par with that of $S_{GA}+F_{GAS}$ and $S_{GA}+F_{GAP}$. At 80 DAS, treatment $S_{GA}+F_{GAS}$ gave the highest value, with its effect being by that of $S_{GA}+F_{GAP}$ and $S_{GA}+F_{GAPS}$. Treatment $S_{GA}+F_{GAPS}$ gave 64.24 and 65.37% higher value at 80 and 90 DAS respectively than F_W (Table 2). Treatment $S_{GA}+F_{GAPS}$ gave the maximum value of seed yield per plant. Its effect was, however, equal to that of $S_{GA}+F_{GAS}$, $S_{GA}+F_{GAP}$ and $S_{GA}+F_{GA}$. Treatment $S_{GA}+F_{GAPS}$ gave 86.14% higher value than F_W. Treatment $S_{GA}+F_{GAPS}$ gave the maximum value of seed protein content. Its effect was, however, equal to that of F_{GAPS}, F_{GA}, $S_{GA}+F_{GA}$, $S_{GA}+F_{GAS}$, F_{GAS}, $S_{GA}+F_{GAP}$, $S_{GA}+F_S$, $S_{GA}+F_P$, F_{GAP}, S_{GA} and F_{PS}. Treatment $S_{GA}+F_{GAPS}$ gave 20.59 % higher value than F_W (Fig.1).

Chickpea is a traditional low-input crop in the farming systems of the Indian subcontinent and the Near East where it is an integral part of the daily diet of the people. The crop is also popular in the Indian Highlands and in Central and South Asia. Because of its adaptability to a wide range of environments, it is being promoted even in countries such as Australia, Canada and USA (Khan *et al.,* 2014). Research on the chickpea crop was neglected for many years and only recently due attention has been paid to it. The amount of work published on chickpea research during the past decade may well equal all that had appeared in the several preceding decades (Mazid and Naqvi, 2014 a & b). Very important crop plants, i.e., legumes species, can obtain a significant portion of their N requirement through symbiotic N_2 fixation when grown in association with effective and compatible *Rhizobium* strain. In crop rotations they improve the N nutrition and yield of subsequent cereals (Mazid and Roychowdhury, 2014).

Plant hormones are also known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates, seed germination, leaf expansion, flower and fruit set, dry matter production, photosynthesis, translocation of food material and synthesis of mRNA coding for hydrolytic enzymes thereby increasing the productivity (Mazid *et al.,* 2010). Though, the plant hormones have great potential, its application and accrual assessments etc. have to be judiciously planned in terms of optimal concentration, stage of application, species specificity and seasons. In their wide spectrum of effectiveness on every aspect of plant growth, even a modest increase of 10-15 per cent could bring about an increment in the gross annual productivity by 10-15 m tons. GA_3 occupies a prominent position in mediating a variety of physiological processes (Mazid *et al.,* 2014 a & b). The superiority of GA_3 has also been substantiated in the author's preliminary experiment (Mazid, 2014c).

Micronutrients though required in minute quantity, their role is the most deciding factor on yield and quality of many crops. The improving effect of the spray of a small quantity of P and /or S alone or in combination with the foliar spray treatment of GA_3 over the respective control on the growth parameters of chickpea cultivar KWR-108 grown with the recommended basal dose of N and P is a noteworthy observation. The promoting effect of P and S on the growth parameters can be traced to their various roles in plant system. Being important essential nutrients, P and S are directly or indirectly involved in the production of metabolic compounds. These metabolites, in turn, encourage the formation and enlargement of new cells in treated plants; hence the increased height of plants, number of branches, leaves dry weight, extra leaf formation and larger specific leaf weight, TDM and LAI (Table 1). It may be added that these results on the improving effect of foliar application of P and S broadly corroborate the earlier findings (Khan, 1993; Naqvi *et al.,* 2014). Moreover, improvement in shoot length, leaf dry weight and LAI would have contributed in improving the ability of treated plants for nodule and biomass production. This is manifested in the observed improvement in their TDM (Mazid *et al.,* 2014a). Dashora and Jain (1994) found that spraying of triacontanol significantly increased LAI in soybean. Kumar (2002) reported that the application of mepiquat chloride or chlormequat decreased the LAI in groundnut. Premabatidevi (1998) found that application of chlormequat, mepiquat chloride decreased the LAI was increased.

Application of GA_3 improves absorption and use efficiency of nutrients (Mazid *et al.,* 2014b), activity of enzymes (Mazid *et al.,* 2013), cell division and cell enlargement (Mazid *et al.,* 2011 a, b), Chl content (Mazid and Mohammad, 2012), elongation of internode (Mazid et al., 2012a), membrane permeability (Mazid *et al.,* 2012b), P_N (Khan *et al.,* 2013), nucleic acid and protein synthesis (Quddasi *et al.,* 2014), and transport of photosynthates (Khan *et al.,* 2012). Foliar application of GA_3 could have led to the observed improvement in plant height, leaf number per plant, and LAI per plant of the treated plants (Khan *et al.,* 2011b). These results broadly corroborate the findings of earlier workers including Khan *et al.* (2011c), Khan and Mazid (2011), Mazid *et al.* (2011a) and Mazid *et al.* (2011b). Like GA_3, foliar spray of other hormones including miraculan increased plant growth in soybean. Double sprays of miraculan enhanced the plant height and number of branches in soybean (Shukla *et al.,* 1997). Also, a significant increase in the number of branches per plant due to the application of CCC in green gram (Mandal *et al.,* 1997).

Furthermore, foliar spray of cycocel reduced the stem length in moongbean. The foliar application of cycocel reduced the plant height and increased the primary branches per plant in green gram. The application of cycocel reduced the plant height in pea. The application of cycocel not only reduced the plant height but also increased the Chl content in sunflower (Garai and Datta, 2003). Morris *et al.* (2003) observed that the application of chamatkar decreased the plant height. In addition, Meena *et al.* (2002) opined that

Table 2: Effect of gibberellic acid, P and S on yield and component traits of chickpea at two sampling stages (80 and 90 days after sowing, DAS) (Cicer arietinum L.)

Treatment	**Nitrate reductase activity (NRA)**		**Total chlorophyll content**		**Nodule-Nitrogen**		**Net photosynthetic rate (P_N)**		**Transpiration rate (Tr)**		**Nitrogenase activity (N-ase)**		**Carbohydrate content**	
	80 DAS	**90 DAS**	**80 DAS**	**90 DAS**	**80 DAS**	**90 DAS**	**80 DAS**	**90 DAS**	**80 DAS**	**90 DAS**	**80 DAS**	**90 DAS**	**90 DAS**	**130 DAS**
F_W	83.33	83.33		84.83	1.690	1.720	2.99	2.60	7.16	6.64	0.234	0.231	1.34	
1.34	37.20													
F_P	89.00	90.86	1.810	1.840	2.30	2.70	8.10	7.54	0.342	0.220	1.43	1.45	38.50	
F_S	93.83	95.12	1.940	1.970	2.84	2.80	8.27	7.84	0.321	0.300	1.40	1.52	40.10	
F_{PS}	94.47	96.41	1.970	2.000	3.10	2.90	9.11	8.84	0.292	0.321	1.52	1.64	40.00	
S_{GA}	84.00	85.88	2.140	2.210	2.40	3.00	7.61	8.20	0.324	0.342	1.49	1.67	39.20	
$S_{GA}+F_P$	85.94	87.05	2.170	2.200	2.50	2.90	8.64	8.29	0.278	0.065	1.65	1.64	38.70	
$S_{GA}+F_S$	94.80	97.27	2.190	2.200	2.60	2.50	8.94	8.40	0.352	0.127	1.69	1.65	40.00	
$S_{GA}+F_{PS}$	99.22	100.94	2.240	2.290	2.70	3.20	9.27	8.24	0.234	0.328	1.78	1.81	40.20	
F_{GA}	84.47	85.33	2.370	2.390	2.50	2.90	9.00	8.97	0.321	0.256	1.50	1.56	43.00	
F_{GAP}	85.27	88.72	2.390	2.400	2.40	2.60	10.44	9.92	0.187	0.327	1.64	1.85	42.90	
F_{GAS}	88.13	91.72	2.350	2.380	2.10	2.50	10.45	9.97	0.189	0.258	1.65	1.63	41.80	
F_{GAPS}	98.86	99.41	2.400	2.410	3.20	3.10	10.40	10.13	0.239	0.321	1.70	1.86	40.50	
$S_{GA}+F_{GA}$	90.50	94.77	2.420	2.500	3.20	3.00	10.40	10.10	0.229	0.300	1.65	1.64	41.00	
$S_{GA}+F_{GAP}$	94.50	96.50	2.440	2.530	3.40	3.40	11.44	10.87	0.320	0.256	1.63	1.84	41.20	
$S_{GA}+F_{GAS}$	96.44	102.88	2.430	2.490	3.50	3.50	11.54	10.98	0.389	0.345	1.76	1.78	43.10	
$S_{GA}+F_{GAPS}$	101.97	103.88	2.470	2.560	3.60	3.60	11.76	10.70	0.432	0.389	1.89	1.98	43.90	
C.D. at 5%	**6.51**	**6.66**	**0.156**	**0.560**	**1.64**	**2.39**	**0.68**	**0.640**	**0.435**	**0.421**	**0.87**	**0.85**	**1.87**	

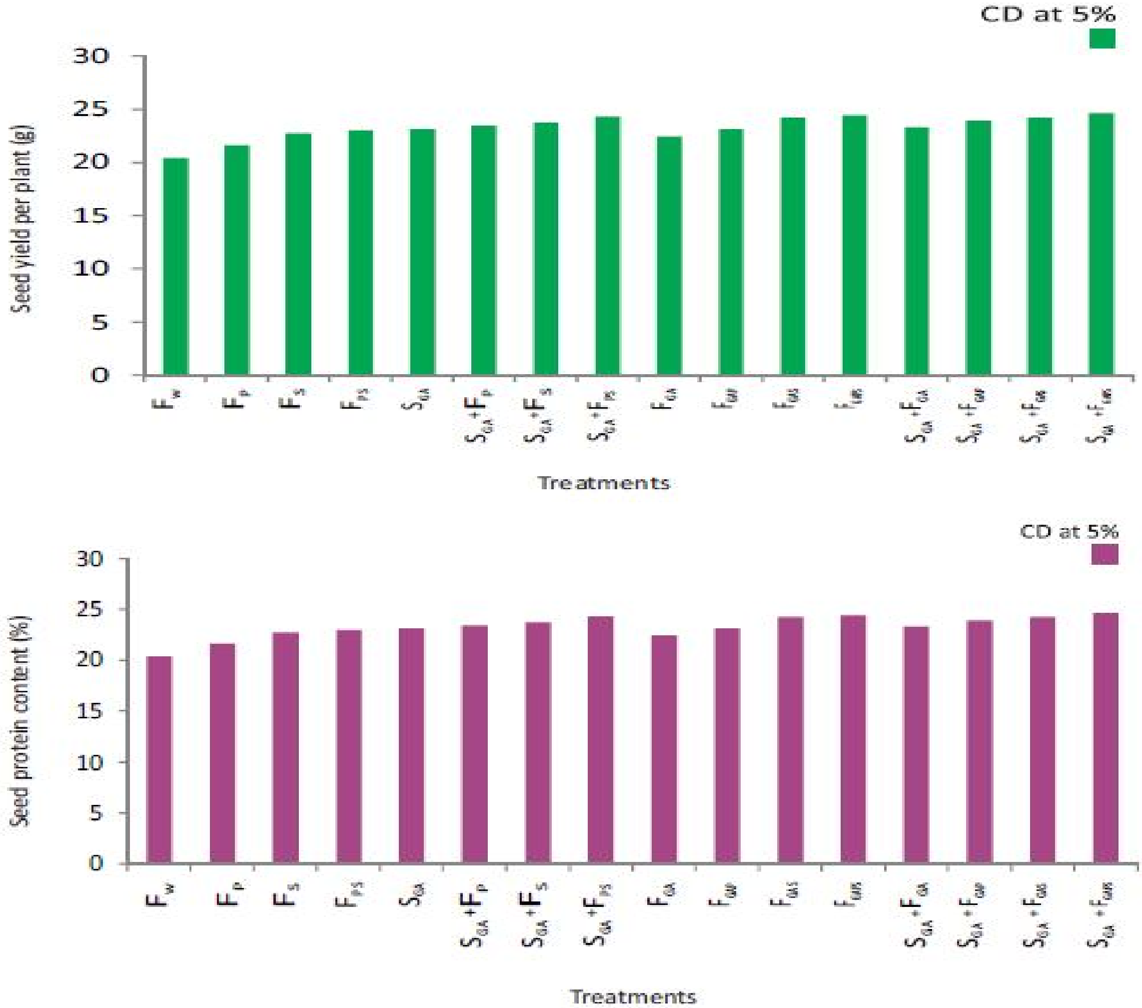

Fig 1: Effect of spray of P and / or S in the presence or absence of soaking and / or spray treatment of GA_3 on (a) seed yield per plant (b) seed protein content of cultivar KWR-108 of chickpea

foliar application of triacontanol and salicylic acid to lentil increased the plant height and number of branches per plant.

Furthermore, Ogilvy (1985) indicated that, foliar application of cycocel, ethephon and mepiquat chloride at the start of the stem extension resulted in retarded vegetative growth in rape. In soybean cultivars, reduction in plant height and increased LAI during the seed filling stage with the foliar spray of cycocel at flower initiation stage (Singh *et al.,* 1987). The application gave better enhancement in growth attributes *viz*., plant height, branches and functional leaves. Dry matter accumulation and partitioning of plant growth, development and economic yield depends on dry matter accumulation and its distribution at various growth stages. Chandrababu *et al.* (1995) noticed that application of mepiquat chloride resulted in maximum leaf weight, total plant dry weight in groundnut. Wasnik and Bagga (1996) reported that application of GA_3 in chickpea increased the leaf dry weight but had no effect on root and stem dry weights.

Mahla *et al.* (1999) noticed that dry matter production was highest in black gram when sprayed with triacontanol and GA_3. Foliar spraying of triacontanol exhibited higher dry matter accumulation in chilli. Singh *et al.* (1993) noticed that application of cycocel has significantly increased the seed yield in mung-bean. Shah and Prathapsenan (1991) studied effect of cycocel on green gram and indicated that there was an increase of leaf dry weight over control. In sunflower, application of cycocel has significantly reduced the stem and leaf dry weight but has increased head dry weight. Application of cycocel increased the allocation of dry matter to the pods.

Besides this, the expansion and differentiation of plant cells are the functions of the plant growth and are affected by environmental factors, plant hormones and nutrients. Dry matter production at each growth stage and its partitioning to reproductive organs during pre-flowering to maturity period has immense importance in determining the productivity. The pattern of translocation of photosynthates changes before and after flowering is important. Kumawat and Khangarot (2002) found that application of S ha significantly increased the plant height. Singh *et al.* (1994) reported that dry matter accumulation has increased significantly with application of S in summer mung. Also, Kale (1993) reported that application of S has given dry matter and yield in groundnut. Shoot dry weight was increased significantly by S addition only after the pod fill stage in pea. Post flowering spraying of nutrient solution (P+S) and urea at flowering and thereafter increased the LAI in groundnut (Patra *et al.,* 1995; Mazid and Khan, 2013).

Biochemical, yield and quality characteristics: Apart from morphological and physiological alterations, plant hormones, nutrients also influence various biochemical parameters and thereby alter yield and quality parameters in various crops. Foliar application of GA_3 increased the Chl content in pea. The augmenting effect of leaf-applied GA_3 over the control as also its superior effect on NR and N-ase activities of chickpea receiving the recommended basal dose of 40 kg N + 30 kg P_2O_5/ha, studied at 80 and 90 DAS is worth mentioning. The increase in NR and N-ase activities can be contributes to the hormone-induced increase in transcription and/or translation of the gene that codes for NR to its role in enhancing the permeability of membrane. These results are in accordance with the data of earlier workers including (Singh *et al.,* 1994).

The augmenting effect of foliar spray of P and /or S alone or in combination with the foliar spray treatment of GA_3 over the respective control on N-ase activity, NR activity of chickpea grown with the recommended basal dose of N and P is not far to seek. P and S being component of the various metabolites involved in the production of organic compounds which encourage the formation and proper supply of proteins to be involved in the formation of enzymes. Hence higher activities of N-ase and NR in treated plants. The NR activity, which is the key enzyme in N-metabolism, is known to be regulated by various environmental factors apart from its own substrate, nitrate. It is also believed that reduction of nitrate to nitrite by NRA is the rate limiting process for the utilization of N in the form of nitrate. NRA was correlated with TDM at early stage but did not have positive correlation with any of the yield and yield components in groundnut (Antony, 1995).

At last, Kumaravelu *et al.* (2000) indicated that foliar spray of triacontanol increased the NR in green-gram. Muthuchelian *et al.* (1995) indicated that foliar spray of triacontanol significantly increased the NR in *Erythrina variegata* seedlings. Wasnik and Bagga (1992) reported that the application of cycocel increased the NR (nitrate reductase) in green-gram leaves. Kumar *et al.* (2002) indicated that foliar application of triacontanol significantly increased the NR in pearl millet. Foliar application of cycocel to sunflower decreased the NR during growth stages while chlormequat decreased NR throughout all growth stages. Singh *et al.* (1994) indicated that the foliar application of GA_3 increased the leaf chlorophyll and decreased the Chl in lentil. Mahla *et al.* (1999) reported that application of triacontanol increased the leaf Chl content in black-gram. S addition significantly increased the leaf Chl content in pea. Application of cycocel increased the leaf Chl content in mung-bean. Enhanced rate of CA activity would have resulted in improving the P_N and *gs* of treated plants. Likewise, increased NR activity might be responsible for increasing biosynthesis of Chl that would have improved P_N of treated plants.

Yield is a complex heritable character influenced by many morphological and physiological characters of plant interacting with environment. Most of the yield components show a direct influence on seed yield. Moreover, the vegetative and reproductive growth of plants depends mainly on their ability to fix C in organs. The C fixing ability of plants is influenced by mineral elements among other factors, the availability of P and S to leguminous plants affects production of dry matter and partitioning of photosynthates (Chaurasia and Chaurasia, 2008). GA_3 combined with a small quantity of spray of P and S could be exploited to enhance the productivity. Application of GA_3 significantly increased the number and weight of pods and the total yield. The application of mepiquat chloride recorded the higher pod yield in groundnut. Also, application of cycocel has given the higher seed yield in cluster-bean. Chandrababu *et al.* (1995) indicated that foliar spray of GA_3 increased the number of mature pods and pod yield and decreased the HI in groundnut. The observed increase in seed protein content due to foliar application and due to foliar treatment of GA_3 is not surprising. An improvement in protein synthesis may result from the application of GA_3 and P and S (Taiz and Zeiger, 2010), hence higher values for photosynthetic enzymes on GA_3 application. Application of cycocel + GA_3 at flowering stage increased the number of pods, number of seeds, seed size and yield per plant in chickpea. Moreover, it mediates differentiation leading to enhanced number of flowers which develop into pods. It plays role in cell division and cell enlargement resulting in proper development of under-developed pods especially at the terminal end of branches; P_N supplying sufficient C skeleton; and membrane permeability and transport of photosynthates favouring partitioning hence higher values for the yield parameters of treated plants. This may be due to its roles in improving the growth and biochemical parameters and offset of the 'hidden hunger' for GA_3 by its foliar application.

Sulphur application significantly increased the pod number and weight per plant and seed yield per plant in cowpea. Naidu and Hanuman Rao (1996) reported that S produced greater number of pods as well as seed yield in green-gram. Kumawat and Khangarot (2002) indicated that in cluster-bean, application of S per ha significantly increased number of pods per plant, number of seeds per pod and seed yield. Spraying of NAA and miraculan at flower initiation and seed filling stages also increased the seed yield in green-gram and black-gram. The increase in seed yield was attributed to reduced plant height and delayed leaf senescence, pods per plant, seeds per pod and 100-seed weight.

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