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GROWTH PARTITIONING AND PRODUCTIVITY OF WHEAT AS INFLUENCED BY FERTILIZATION AND FOLIAR APPLICATION OF BIO-REGULATORS

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SUMMARY

A field experiment was conducted to study the response of wheat to N, P, K, S and Zn nutrients (varying combinations) along with foliar application of bio-regulators (brassinosteroid 0.5 ppm, thiourea 1000 ppm and kinetin 10 ppm) during two consecutive years. Crop under NPKSZn fertilization attained maximum growth, chlorophyll content and dry matter accumulation in plant parts. It resulted in significantly improved productivity over other treatments including NPKS and NPKZn, which were also found superior over sole application of N, NP and NPK. Application of bio-regulators significantly improved growth parameters viz., plant height, dry matter accumulation, CGR, RGR and chlorophyll content as well as grain yield over control. Among the bio-regulators, brassinosteroid (0.5 ppm) recorded maximum improvement in all these parameters followed by kinetin (10 ppm). Harvest index improved significantly as a result of bio-regulator application over control.

Key words: **Bio-regulators, dry matter partitioning, fertilization, growth efficiency, wheat, yield**

INTRODUCTION

Despite significant achievements through green revolution, there is need of further enhancement in wheat production to feed ever burgeoning population and strengthening food security. It has been estimated that India will need at least 109 million tonnes of wheat by 2020 as against present production of 73.3 million tonnes from an area of 25.5 million hectare (Mishra 2006). Balanced nutrition of plants is one of the most important factor determining crop productivity. The factor productivity of N as well as P has gone down with the passage of time due to deficiency of other nutrients such as K, Zn, S, Fe and so on. Presently, addition of K, S and Zn are also necessary part of balanced fertilization to achieve higher efficiency of applied nutrients and to enhance productivity of wheat.

Partitioning of dry matter (DM) to seeds is considered to be a major determinant for agricultural yield. This is dependent on the efficiency of photosynthate translocation in crop during grain filling period when developing grains are the storing sink. It has been reported that bio-regulators plays important role in greater partitioning of photosynthates towards reproductive sink thereby, improving the harvest index. Foliar applications of brassinosteroid (Sairam 1994), thiourea (Sahu and Singh 1995) and kinetin (Hegazi *et al.* 1996) have been reported to be effective for enhancing wheat productivity under different environmental conditions. Therefore, present experiment was undertaken with the aim of selecting most efficient and potential bio-regulator for wheat along with balanced use of fertilizers.

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MATERIALS AND METHODS

The field experiments were conducted at Mechanized Agriculture Farm, A.R.S.,Ummedganj, Kota during two consecutive *rabi* seasons of 2004-2005 and 2005-2006. The Soil was clay loam in texture with organic carbon 0.61%, pH 7.9 (1:2.5 soil: water ratio) and electrical conductivity 0.54 dSm^{-1} (1:2 soil: water ratio). The available soil N, P and K were 299.7, 18.6, 362.5 kg ha^{-1}, respectively. Available S and DTPA-extractable Zn in soil were 8.8 and 0.44 mg kg^{-1}, respectively. The experiment comprised of twenty-four treatment combinations with six levels of balanced fertilization as N, NP, NPK, NPKS, NPKZn and NPKSZ @ 120 kg N, 17.2 kg P, 24.9 kg K, 40 kg S, 5.5 kg Zn ha^{-1} and four levels of bio-regulators (water spray: control, brassinosteroid: 0.5 ppm, thiourea: 1000 ppm and kinetin: 10 ppm). The treatments were replicated thrice in a factorial randomized block design. The half dose of N and full dose of P and K and were drilled at sowing time through urea, diammonium phosphate and muriate of potash, respectively, and half dose of N was top dressed in two equal splits at first and second irrigations. The S and Zn were applied as basal dose as gypsum and zinc oxide, respectively. The foliar sprays of each bio-regulator were made at two growth stages viz., first at maximum tillering (45-50 days after sowing -DAS) and second at ear emergence (70-75 DAS) using spray volume of 600 litre ha^{-1}. In order to make sprays more effective, teepol was mixed @ 0.5 ml l^{-1} with spray solution as a sticking agent. Wheat variety 'GW-322' was sown at 23 cm spaced furrows using seed rate of 100 kg ha^{-1}. Five irrigations were applied uniformly at critical growth stages i.e. crown root initiation, tillering, late jointing (boot), flowering and milk stage. The data on periodical dry matter (DM) accumulation in stem, leaves and ears were recorded by collecting whole plant samples from randomly selected two rows of 0.5 m length at maximum tillering (45-50 DAS), flowering (80-85 DAS), milk (95-100 DAS) and harvest (physiological maturity) stages.

The growth efficiency parameters namely, crop growth rate (CGR) and relative growth rate (RGR) between maximum tillering to flowering and flowering to harvest stages were computed on the basis of dry matter accumulation, by using formulas given by Redford (1967). Total chlorophyll content of fresh leaf samples (80 DAS) was estimated by the method suggested by Arnon (1949). The above ground portion of plants after harvest were sun dried for one week and than weighed to work out biomass yield. After threshing and winnowing, grain yields from each plot were weighed separately. The harvest index was computed as suggested by Donald and Hamblin (1976). All the data were subjected to statistical analysis by adopting appropriate method of analysis of variance for testing the significance of variation in experimental results (Panse and Sukhatme 1985).

RESULTS AND DISCUSSION

Results (Table 1-3) revealed that balanced fertilization involving application of NP, NPKS, NPKZ and NPKSZn had a significant and positive influence on various growth parameters and productivity of wheat. Application of NPKSZn resulted in accumulation of maximum DM in stem, leaves as well as ears at successive stages (Table 1), which proved significantly superior over rest of the treatments. NPKS and NPKZn treatments also accumulated significantly higher DM in leaves, stem and ears over N, NP and NPK. Application of NPKSZn increased total DM accumulation to the extent of 109.2, 147.1 and 179.5 g m^{-2} over NPK at maximum flowering, milk and harvest stages, respectively. DM distribution pattern among plant parts at harvest stage did not show much variation due to balanced fertilization treatments, however, N alone fertilization contributed higher DM towards stem (32.25 %) as compared to NP (31.23%), NPK (31.13 %), NPKS (30.61 %), NPKZn (30.56 %) and NPKSZn (30.48%). Further, DM distribution among leaves and ears were observed in the range of 7.38- 8.28 and 60.37-61.37 per cent, respectively, with minimum being under N alone and maximum with NPKSZn and NPKZ treatments.

Growth was significantly improved due to application of various nutrient combinations (Table 2). Highest CGR between maximum tillering to flowering as well as flowering to harvest stages, was recorded under the application of NPKSZn followed by NPKS and NPKZn fertilization, which were significantly higher over N, NP and NPK. As compared to N alone, all the fertilization

Table 1. Effect of balanced fertilization and bio-regulators on DM accumulation and it's partitioning among stem, leaves and ears at successive growth stages in wheat. (pooled data of two seasons)

	DM accumulation at flowering stage ($g\ m^{-2}$)				DM accumulation at milk stage ($g\ m^{-2}$)				DM accumulation at harvest stage ($g\ m^{-2}$)			
	Stem	**Leaves**	**Ears**	**Total**	**Stem**	**Leaves**	**Ears**	**Total**	**Stem**	**Leaves**	**Ears**	**Total**
A) Balanced fertilization												
N	301.0	145.1	155.8	601.9	329.9	118.5	338.8	787.2	309.5	70.9	579.1	959.5
N P	343.9	177.5	192.9	714.3	385.0	146.7	417.2	948.9	361.1	89.9	706.7	1157.7
N P K	351.3	180.3	197.2	728.8	390.9	151.1	423.6	965.6	367.3	93.5	721.0	1181.8
N P K S	383.9	202.9	216.3	803.1	427.4	172.1	468.8	1068.3	398.4	105.7	798.6	1302.7
N P K Zn	373.9	200.2	212.7	786.8	419.9	169.1	461.6	1050.6	390.0	103.4	784.2	1277.6
N P K S Zn	396.4	213.3	228.3	838.0	439.7	182.0	490.9	1112.6	414.3	113.0	834.0	1361.3
SEm+	3.12	2.30	2.76	5.91	2.61	2.30	5.12	6.72	3.93	2.10	7.72	10.76
CD(P=0.05)	8.8	6.5	7.8	16.6	7.3	6.5	14.4	18.9	11.0	5.1	21.7	30.2
B) Bio-regulators (foliar spray)												
Control (water spray)	348.5	174.0	184.8	707.3	389.9	140.7	398.1	928.7	363.9	87.3	676.6	1127.8
Brassinosteroid 0.5 ppm	366.3	194.5	209.9	770.7	405.3	164.7	455.2	1025.2	384.3	101.9	769.4	1255.6
Thiourea 1000 ppm	358.9	186.8	199.9	745.6	398.8	157.1	437.2	993.1	369.8	95.5	745.1	1210.4
Kinetin 10 ppm	360.0	190.7	207.5	758.2	401.1	163.8	443.5	1008.4	375.8	99.5	757.9	1233.2
SEm+	2.54	1.88	2.25	4.83	2.13	1.88	4.18	5.48	3.21	1.71	6.30	8.79
CD(P=0.05)	7.2	5.3	6.3	13.6	6.0	5.3	11.7	15.4	9.0	4.8	17.7	24.7

treatments resulted in significantly higher RGR between maximum tillering to flowering stage. However, fertilization treatments other than N alone, remained at par among themselves on this parameter. Further, RGR estimated between flowering to harvest stage did not show significant variation due to balanced fertilization.

As evident from results (Table 2), total chlorophyll content (80 DAS) was significantly increased due to P, S, Zn and S+Zn fertilization. Maximum chlorophyll content was observed under NPKSZn, which was significantly superior over rest of the treatments. Application of NPKS and NPKZn also resulted in significantly higher chlorophyll content over N, NP and NPK. Adequate nutrient supply under balanced fertilization enhanced the synthesis of chlorophyll. Among nutrients, S is a constituent of S containing amino acids and influences synthesis of chlorophyll, protein and functioning of several enzyme systems, thereby, required for many physiological and metabolic processes in plants. Zn plays important role in synthesis of various enzymes, N metabolism and several oxidation-reduction reactions. Zn improves efficiency of chloroplasts to capture solar energy through enzyme carbonic anhydrase. Therefore, development of greater assimilating apparatus (leaves) together with higher chlorophyll content might have resulted in better interception and utilization of radiant energy leading towards greater photosynthetic efficiency and ultimately greater DM accumulation under the influence of S and Zn fertilization along with NPK.

Influence of balanced fertilization on growth parameters seems to be on account of their role in maintaining congenial nutritional environment in soil and plant system. The soil of the experimental site was deficient in S and Zn. Therefore, application of S and Zn nutrients enriched the soil and improved availability to roots resulting in greater nutrient absorption and translocation. Whereas, status of available K in soil was

Table 2. Effect of balanced fertilization and bio-regulators on total chlorophyll content in leaves (80DAS), crop growth rate (CGR) and relative growth rate (RGR) in wheat. (pooled data of two seasons)

Treatments	Total chlorophyll ($mg\ g^{-1}$ fw)	CGR ($g\ m^{-2}\ day^{-1}$)		RGR ($g\ g^{-1}\ day^{-1}$)	
		Max. tillering to flowering	Flowering to harvest stage	Max. tillering to flowering	Flowering to harvest stage
A) Balanced fertilization					
N	2.116	11.568	9.172	0.0319	0.0119
N P	2.362	14.177	11.373	0.0339	0.0124
N P K	2.391	14.473	11.621	0.0339	0.0124
N P K S	2.634	16.037	12.814	0.0343	0.0124
N P K Zn	2.593	15.688	12.588	0.0342	0.0124
N P K S Zn	2.739	16.728	13.423	0.0343	0.0125
SEm+	0.019	0.182	0.175	0.00037	0.00013
CD(P=0.05)	0.054	0.510	0.491	0.0010	NS
B) Bio-regulators (foliar spray)					
Control (water spray)	2.278	13.668	10.784	0.0322	0.0119
Brassinosteroid 0.5 ppm	2.583	15.468	12.438	0.0346	0.0125
Thiourea 1000 ppm	2.483	14.760	11.921	0.0337	0.0124
Kinetin 10 ppm	2.546	15.218	12.185	0.0346	0.0125
SEm+	0.016	0.148	0.143	0.00030	0.00011
CD(P=0.05)	0.044	0.416	0.401	0.0009	0.0003

high, therefore, it's application did not bring significant influences on any of the growth parameters.

The crop under the influence of NPKSZn recorded maximum and significantly higher grain and biomass yields (Table 3) over rest of the treatments. In this regard, NPKS proved next best nutrient combination which was closely followed by NPKZn. Additional fertilization of each nutrient (except K) bought additional increment over its preceding nutrient combination, therefore, maximum yields were recorded when NPKSZn were applied. On pooled data basis, NP fertilization in comparison to N alone, provided an additional biomass yield of 1978 kg ha^{-1}. Further, addition of S and Zn with NPK resulted in additional increment of 1121 and 861 kg ha^{-1}, respectively over NPK. These responses of P, S and Zn were greatly reflected under the application of NPKSZn, which in turn produced more biomass yield of 3992, 2015, 1719, 598 and 858 kg ha^{-1} over N, NP, NPK, NPKS and NPKZn, respectively.

In present investigation, all the three bio-regulators (brassinosteroid 0.5 ppm, thiourea 1000 ppm and kinetin 10 ppm) significantly improved growth parameters and productivity of wheat (Table 1-3). All these bio-regulators significantly enhanced DM of stem, leaves as well ears at all growth stages, except thiourea wherein, improvement in stem DM was not recorded at harvest as compared to control. At harvest stage, application of brassinosteroid increased DM of stem, leaves and ears to the extent of 20.42, 14.55 and 92.85 g m^{-2}, respectively over control. Corresponding increment due to application of thiourea and kinetin were in the order of 5.86 (NS), 8.26 & 68.51 g m^{-1} row and 11.91, 12.19 & 81.34 g m^{-2}, respectively, over control. Thus, results indicate positive impact of the bio-regulators on overall growth of wheat crop.

Based on data (Table 1), it has been noted that at harvest stage, bio-regulator treatments had greater distribution of total DM towards ears and decreased contribution in stem DM as compared to control. DM distribution towards ears came to be 59.97, 61.24, 61.52 and 61.42 per cent of the total DM under control, brassinosteroid, thiourea and kinetin treatments, respectively. The corresponding values for stem were

Table 3. Effect of balanced fertilization and bio-regulators on plant height, biomass yield, grain yield and harvest index in wheat. (pooled data of two seasons)

Treatments	Plant height (cm)	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
(A) Balanced fertilization				
N	88.75	9837	4270	43.39
N P	93.05	11815	5198	43.99
N P K	94.44	12110	5361	44.26
N P K S	99.13	13231	5869	44.32
N P K Zn	97.73	12971	5790	44.62
N P K S Zn	100.15	13829	6160	44.52
SEm+	0.627	112.1	59.5	0.303
CD (P=0.05)	1.77	315	167	NS
(B) Bio-regulators (foliar spray)				
Control (water spray)	92.74	11565	4988	43.12
Brassinosteroid 0.5 ppm	97.26	12788	5692	44.44
Thiourea 1000 ppm	96.24	12312	5483	44.50
Kinetin 10 ppm	95.92	12531	5603	44.66
SEm+	0.512	91.5	48.6	0.248
CD(P=0.05)	1.44	257	136	0.70

in the order of 32.31, 30.70, 30.61 and 30.56 per cent, respectively. While leaves DM varied between 7.72 - 8.07 per cent of total DMA, with minimum being in control and maximum in brassinosteroid.

Significant impact on growth parameters were noted in all the bio-regulator treatments over control (Table 2). During both growth phases, maximum CGR were recorded with brassinosteroid followed by kinetin with non-significant difference. In this respect, brassinosteroid proved significantly better over thiourea. All the bio-regulators showed significantly higher RGR values of both growth phases over control. Higher CGR and RGR under bio-regulators might be associated with increased cell division and elongation by virtue of increased photosynthetic efficiency due to improvement in chlorophyll content and better developed assimilating apparatus, and hence, increased DM accumulation at every growth stage. Several workers have reported enhancement in photosynthetic efficiency due to application of brassinosteroid (Sairam 1994), thiourea (Sahu *et al*. 1993) and kinetin (Biswas and Mandal 1988).

Foliar application of bio-regulators resulted in significantly increased chlorophyll content (80 DAS) over control. The increase in chlorophyll content with bio-regulators application has been reported by many workers. Maximum chlorophyll content recorded under brassinosteroid was significantly higher over thiourea but remained at par with kinetin.

Among these bio-regulators, brassinosteroid exhibited maximum promotion in growth parameters followed by kinetin. The significant positive impact of brassinosteroid on overall growth of wheat plants seems to be on account of its regulatory role played in cell elongation and division. It has been reported that brassinosteroid induced growth in plants is mediated through nucleic acid metabolism. The involvement of brassinosteroid in transcription and replication during tissue growth leading to increase in enzyme activities, apparently affect nucleic acid metabolism such that the levels of accumulated RNA, DNA and protein in the tissue increases during growth (Kalinich *et al*. 1985). Positive effect of brassinosteroid on nitrate reductase, glutamine synthetase activities, photosynthesis, chlorophyll content and total soluble protein in wheat plants grown in under water stress and adequate water conditions was observed by Sairam (1994). In present study, brassinosteroid proved significantly better over thiourea with regards to DM accumulation at every growth stage which could be due to significantly higher chlorophyll. Application of brassinosteroid might have helped in better rooting, enhanced uptake of more nutrients than thiourea. Mandava (1988) opined that brassinosteroid significantly stimulate root growth which results in greater secretion of organic acids, thus increases availability of nutrients. Thus, higher chlorophyll contents together with better developed plant canopy might have maintained higher photosynthetic efficiency as reflected in significantly better CGR and RGR during maximum tillering to flowering under brassinosteroid in comparison to thiourea.

Growth promotion under application of thiourea might be on account of increased photosynthetic efficiency as well as due to its positive impact on translocation of photosynthetic assimilates towards active sink. Thiourea might have helped in maintaining photosynthetically active leaves as indicated by significantly higher leaf DM and chlorophyll content under thiourea over control. Since thiourea contains –SH group, thiourea may play several bio-regulatory role in crop plants as the –SH group has diverse biological activity. Since the –SH group is essential at the the subtstrate binding site of amino acid carrier (McCormick and Johnstone 1990), thiourea may also enhance formation of ternary complex, sucrose-H+ carrier, thus improving phloem loading of sucrose and hence translocation of sucrose. In present investigation, application of thiourea might have improved phloem loading of sucrose and hence translocation of photosynthates.

Kinetin is known to promote cell division, retards senescence of leaves, keeping assimilating organs green and active for longer period (Michael *et al*. 1970). In present investigation, kinetin application increased chlorophyll content, growth efficiency parameters viz., CGR and RGR and biomass accumulation in leaves as compared to control, which indicate the role played by kinetin in delaying senescence and keeping assimilating organs active for longer period. Kinetin application might have enhanced meristematic activity, thereby increased division, enlargement and elongation of cells resulting in higher DM accumulation and plant height. Increased DM accumulation and plant height due to exogenous application of kinetin in wheat was also observed by Verma *et al*. (2004).

Application of each bio-regulators brought about significant improvements in productivity as compared to control. Maximum increment in grain yield over control was recorded due to brassinosteroid application (14.10%) followed by kinetin (12.31%) and thiourea (9.92%). Corresponding increment in biological yields were in the order 10.58, 6.46 and 8.35 per cent, respectively, over control. Maximum grain and biomass yields recorded with brassinosteroid, were also found statistically better over thiourea. Greater photosynthetic efficiency under bio-regulators might have provided adequate metabolites to reproductive sinks for greater growth and development. A critical examination of data on DM partitioning (Table 1) reveal that bio-regulators partitioned relatively more DM towards ears in comparison to leaves and stem. Moreover, thiourea did not bring significant increment in stem DM at harvest stage. In cereals, most of the carbohydrate in grain results from photosynthesis after anthesis. Therefore, photosynthetic capacity of the crop at anthesis and the duration of that capacity are of considerable importance and in present study, both were significantly increased due to bio-regulators application as evident from higher values of chlorophyll content, leaves DM and growth efficiency parameters over control.

Brassinosteroid recorded significantly higher DM accumulation right from flowering to harvest stages due to higher growth efficiency during maximum tillering to flowering, which could be reasoned for significantly better biomass and grain yields over thiourea.

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