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RESEARCH ARTICLE

INFLUENCE OF PUTRESCINE AND INDOLE-3-BUTYRIC ACID ON CHEMICAL AND BIOCHEMICAL PARAMETERS AND YIELD OF SOYBEAN

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ABSTRACT

An experiment was conducted at Botany Section, College of Agriculture, Nagpur (MS) India during year 2014-2015 to study the influence of putrescine and IBA (50, 75,100,125, 150 ppm each) on chemical, biochemical, yield and yield contributing parameters of soybean. Experiment was conducted in Randomized Block Design. Considering the treatments under study two foliar sprays of 100 ppm putrescine and 100 ppm IBA at two stages ie., before flowering and 10 days after flowering were found to be most effective in improving nitrogen, phosphorus, potassium, chlorophyll content in leaves and protein and oil content in seeds. Yield contributing parameters *viz.,* number of pods plant^{-1}, weight of 100 seeds were also significantly enhanced. Seed yield ha^{-1} was also significantly increased by 100 ppm putrescine (25.89%) and 100 ppm IBA (20.34%) over control.

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INTRODUCTION

Soybean is one of the important oilseed as well as leguminous crop. It is gaining importance in India and other developing countries to ward off malnutrition. Due to its high nutritive value soybean cultivation has taken great strides during the recent years. It is the cheapest and richest source of high quality protein. It supplies most of the nutritional constituents essential for human health. Hence, soybean is called as "Wonder crop" or "Golden bean" or "Miracle bean". This crop in fact has made revolution in the agricultural economy with its immense potential, quality as food, feed, numerous industrial product commodity. It is soil erosion resistant crop and suited for most of the soil. Soybean protein contents all the essential amino acids vital for human diet. Besides protein and oil, soybean contains 20.9 % carbohydrate, 60 % polyunsaturated fatty acids (52.3 % linolenic acid + 7.29 % linoeic acid), Vitamin A, VitaminB, Vitamin C, D, E, K, 0.69 % phosphorus, 0.0115 % iron, 0.0024 % calcium and all the essential amino acids.

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Amongst oil seed crops it has highest content of lysine (5 %), a limiting factor in cereals. So it is called "Poor mans meal" it's a really true. Considering the importance of soybean from nutritional and production point of view, it becomes necessary to cultivate soybean crop with expectation of higher yield. The crop productivity can be increased through physiological approaches by co-ordinating plant process to synthesize dry matter and partitioning its major quantum of effective yield contributing factors. The yield of soybean may be enhanced through physiological manipulation such as foliar application of putrescine and IBA.

Growth mainly refers to quantitative increase in the plant body whereas the qualitative changes refer to development. According to Krishnamoorthy (1981) growth and development of the plant are controlled by internal factors, namely nutritional and hormonal. Nutrional factors supply the plants necessary minerals. They constituent the raw materials required for growth. However, utilization of these substances for a balanced development of the plant body is controlled by certain growth regulators. Plant growth regulators are substances when added in small amounts modify the growth of plant usually by stimulating or inhibiting part of the natural growth regulation.

They are considered as new generation of agrochemicals after fertilizers, pesticides and herbicides. Plant growth regulators are capable of increasing yield by 100-200 per cent under laboratory conditions, 10 -15 per cent in the field conditions. Plant growth regulators like promoters, inhibitors or retardants play a key role in internal control mechanism of plant growth by interacting with key metabolic processes such as nucleic acid and protein synthesis. The most commonly used growth regulators in soybean are IBA, putrescine, Ethrel, cycocel, salicyclic acid, IAA, GA_3 etc. are enhancing growth and productivity of crop plants. Plant growth regulators are shown to change leaf resistance by altering stomatal aperture, the rate of photosynthesis could be manipulated through this technology. Putrescine, IBA, IAA, GA, kinetin, phenolics and aliphatic alcohols are reported to increase and stimulate the rate of photosynthesis. The diamine putrescine occurred widely in the higher plants. It was suggested to be involved in a variety of growth and developmental processes such as cell division (Bueno and Matilla, 1992), fruit set and growth (Biasi *et al*., 1991) and senescence (Kao,1994).

IBA is a plant growth regulator, used to promote and accelerate root formation of plant clippings and to reduce transplant shock of non-food ornamental nursery stock. IBA is also used on fruit and Vegetable crops, field crops and ornamental turf to promote growth development of flowers and fruit and to increase crop yields. IBA has been classified as a biochemical pesticide because it is similar in structure and function to the naturally-occurring plant growth hormone indole-3-acetic acid. Application of growth promoting hormones is a recent technique in this direction. Plant hormones in a broad sense are organic compounds which play an important role in plant growth development and yield of crops to prevent the fruit and flower drop for a longer period. Considering the above aspect the current research work was carried out with the objective to find the influence of putrescine and indole -3-butyric acid on chemical, biochemical, yield and yield contributing parameters of soybean.

MATERIALS AND METHODS

The present investigation was undertaken during the *kharif* season of 2014-2015. The experiment was laid out in randomized block design with eleven treatments and three replications at farm of Botany section, College of Agriculture, Nagpur. Plot size of individual treatment was gross 2.10 m x 2.2 m and net 1.5 m x 2.0 m. Seeds of soybean variety JS-335 were sown at the rate of 75 kg ha^{-1} by dibbling method at spacing of 30 cm X 10 cm on 14^{th} July 2014. Treatments comprised of T_1 (control), T_2 (50 ppm putrescine), T_3 (75 ppm putrescine), T_4 (100 ppm putrescine), T_5 (125 ppm putrescine), T_6 (150 ppm putrescine), T_7 (50 ppm IBA), T_8 (75 ppm IBA), T_9 (100 ppm IBA), T_{10} (125 ppm IBA) and T_{11} (150 ppm IBA). The foliar application of putrescine and IBA was given at two stages i.e. before flowering and 10 days after flowering on soybean. The chemical and biochemical observations *viz.,* Leaf chlorophyll content was estimated by colorimetric method as suggested by Bruinsma, (1982), nitrogen content in leaves was determined by micro-kjeldhal's method as given by Somichi *et al*. (1972), phosphorus content in leaves was determined by vanadomolybdate yellow colour method as given by Jackson (1967) and potassium content in leaves was determined by flame photometer by di-acid extract method given by Jackson (1967) at 30, 45, 60 and 75 DAS. For estimating protein content in seed (%), nitrogen content in seed was determined by micro-kjeldhal's method (Somichi *et al.,*1972) and same was converted into crude protein by multiplying 'N' percentage with factor 5.76. Oil content in seed (%) was estimated by Soxhlet's procedure described by Sankaran (1965). Observations on yield and yield contributing parameters like, number of pods $plant^{-1}$, 100 seed weight and seed yield $hectare^{-1}$ were also recorded. The data collected were subjected to statistical analysis by employing the method for RBD as suggested by Panse and Sukhatme (1954). The F-test was applied to determine the significance of all treatments. Standard error and critical difference at 5% level of probability was used for comparing treatment differences.

RESULTS AND DISCUSSION

The chemical and biochemical studies viz., N, P, K and chlorophyll content in leaves as well as protein and oil content in seeds estimated at various stages of observations have been presented here under.

Leaf nitrogen content

Nitrogen is key component in mineral fertilizers and has more influence on plant growth, appearance and fruit production or quality than any other essential elements. Nitrogen is an important constituent of protein and protoplasm and essential for the growth of plants. Its storage leads to chlorosis and stoppage of growth and its presence in moderate doses is essential for plant growth and fruiting. An abundant supply of essential nitrogenous compound is required in each plant cell for normal cell division, growth and respiration. The N present mostly as protein is constantly moving and under concentration of N is found in young, tender plant tissues like tips of shoots, buds and new leaves (Jain, 2010).

It is observed from the data that there was significant variation in leaf nitrogen content due to foliar sprays of different concentrations of putrescine and IBA at 45, 60, 75 DAS except 30 DAS. Data are presented in Table 1. At 45 DAS nitrogen content was significantly more in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) when compared with treatment T_1 (control). Remaining treatments under study were found at par with treatment T_1 (control). The range of N content at 45 DAS in soybean was 2.38-2.64 %. At 60 DAS nitrogen content was significantly maximum in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine) and T_8 (75 ppm IBA) in a descending manner when compared with treatment T_1 (control). While, remaining treatments were found at par with treatment T_1 (control). The range of N content at 60 DAS in soybean was 2 .30-2.50 %. At 75 DAS nitrogen content was significantly maximum in treatment T_4 (100 ppm putrescine) followed by the treatment T_9 (100 ppm IBA) when compared with treatment T_1 (control) and other remaining treatments under study. While, rest of the treatments were found at par with treatment T_1 (control). The range of N content at 75 DAS in soybean was 1.89-2.11%.

Table 1. Effect of putrescine and IBA on chemical parameters of soybean

Treatments	Leaf nitrogen content (%)				Leaf phosphorus content (%)				Leaf potassium content (%)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
T_1 (Control)	1.50	2.38	2.30	1.89	0.32	0.39	0.59	0.44	0.95	1.18	2.10	1.31
T_2 (50 ppm Putrescine)	1.52	2.42	2.34	1.94	0.35	0.42	0.65	0.51	0.94	1.27	2.19	1.39
T_3 (75 ppm Putrescine)	1.48	2.57	2.43	2.01	0.34	0.49	0.70	0.58	1.22	1.44	2.27	1.78
T_4 (100 ppm Putrescine)	1.51	2.64	2.50	2.11	0.37	0.54	0.77	0.60	1.23	1.51	2.40	1.87
T_5 (125 ppm Putrescine)	1.54	2.48	2.38	1.97	0.31	0.46	0.67	0.55	0.99	1.40	2.21	1.69
T_6 (150 ppm Putrescine)	1.49	2.44	2.35	1.95	0.33	0.43	0.66	0.52	1.08	1.31	2.20	1.48
T_7 (50 ppm IBA)	1.48	2.42	2.31	1.90	0.32	0.40	0.62	0.49	1.03	1.24	2.17	1.37
T_8 (75 ppm IBA)	1.50	2.51	2.41	1.99	0.36	0.45	0.68	0.54	0.97	1.41	2.24	1.71
T_9 (100 ppm IBA)	1.55	2.61	2.49	2.08	0.34	0.50	0.71	0.59	0.98	1.47	2.35	1.83
T_{10} (125 ppm IBA)	1.53	2.44	2.35	1.94	0.37	0.43	0.64	0.52	1.12	1.37	2.19	1.62
T_{11} (150 ppm IBA)	1.52	2.43	2.32	1.91	0.35	0.41	0.62	0.50	1.09	1.30	2.18	1.46
SE (m) ±	0.079	0.052	0.033	0.041	0.017	0.023	0.029	0.027	0.074	0.066	0.052	0.083
CD at 5%	-	0.153	0.099	0.123	-	0.069	0.086	0.082	-	0.197	0.154	0.247

Table 2. Effect of putrescine and IBA on biochemical parameters of soybean

	Leaf chlorophyll content (mg g^{-1})					
Treatments	30 DAS	45 DAS	60 DAS	75 DAS	Protein content (%)	Oil content (%)
T_1 (Control)	1.31	1.72	2.02	1.99	35.91	19.81
T_2 (50 ppm Putrescine)	1.39	1.76	2.05	2.03	37.66	20.99
T_3 (75 ppm Putrescine)	1.28	1.86	2.18	2.16	39.57	21.88
T_4 (100 ppm Putrescine)	1.45	2.03	2.23	2.21	41.97	22.75
T_5 (125 ppm Putrescine)	1.43	1.82	2.10	2.08	38.02	21.22
T_6 (150 ppm Putrescine)	1.44	1.75	2.08	2.06	37.78	21.00
T_7 (50 ppm IBA)	1.30	1.79	2.08	2.07	37.32	20.17
T_8 (75 ppm IBA)	1.34	1.92	2.13	2.10	38.83	21.39
T_9 (100 ppm IBA)	1.32	1.97	2.19	2.17	40.34	22.24
T_{10} (125 ppm IBA)	1.26	1.83	2.11	2.08	37.97	20.98
T_{11} (150 ppm IBA)	1.32	1.81	2.09	2.08	37.42	20.29
SE (m) ±	0.099	0.053	0.040	0.039	1.083	0.533
CD at 5%	-	0.159	0.121	0.117	3.200	1.575

Table 3. Effect of putrescine and IBA on yield and yield contributing parameters of soybean

Treatments	No. of pods $plant^{-1}$	100 seed weight (g)	Seed yield ha^{-1} (q)	Per cent increase in yield
T_1 (Control)	82.13	8.61	17.84	-
T_2 (50 ppm Putrescine)	97.46	9.52	18.58	04.14
T_3 (75 ppm Putrescine)	123.20	10.79	20.07	12.50
T_4 (100 ppm Putrescine)	132.86	11.69	22.46	25.89
T_5 (125 ppm Putrescine)	115.46	10.72	19.90	13.45
T_6 (150 ppm Putrescine)	100.53	9.82	19.44	08.96
T_7 (50 ppm IBA)	93.53	10.32	18.35	02.85
T_8 (75 ppm IBA)	110.46	10.47	19.58	09.75
T_9 (100 ppm IBA)	128.46	11.11	21.47	20.34
T_{10} (125 ppm IBA)	109.06	10.36	19.29	08.12
T_{11} (150 ppm IBA)	100.46	10.06	19.07	06.89
SE (m) ±	6.591	0.305	0.266	-
CD at 5%	19.47	0.902	0.787	-

From this data it is observed that leaf nitrogen content was increased upto 60 DAS and reduced thereafter at 75 DAS. The decrease in nitrogen content might be due to fact that younger leaves and developing organs, such as seeds act as strong sink demand and may draw heavily nitrogen from older leaves (Gardner *et al*., 1988).

Putrescine or IBA enhances enzymatic activity and translocation processes from leaves to seeds, linking or converting to other plant metabolites (Amin *et al*., 2013). Similarly IBA increases the ability of cell division in meristematic zones of plant and hence increases the ability of plant to absorb more nutrients (Ghodrat *et al*., 2012). These might be the reasons for increase in leaf nitrogen content in the present investigation by the application of putrescine and IBA. Amin *et al*. (2013) tested two plant growth regulators putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1} applied either alone or in combinations. Spraying of putrescine and IBA @ 100 mg l^{-1} significantly enhanced nitrogen content of chickpea (*Cicer arientinum* L.). Ahmed *et al*. (2013) conducted a field experiment to study the effect of putrescine (0, 1 and 2 ppm) and humic acid (0, 1 and 2 %) were sprayed eight times started at 45 DAP and repeated every after 15 days on cotton and reported that foliar application of 2 ppm putrescine and 1% humic acid significantly enhanced inorganic nitrogen.

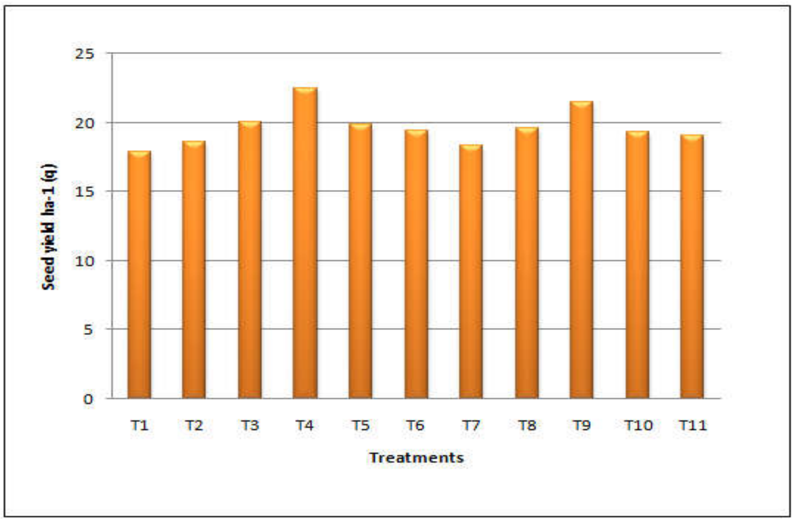

Figure 1. Effect of putrescine and IBA on seed yield ha^{-1} (q) in soybean

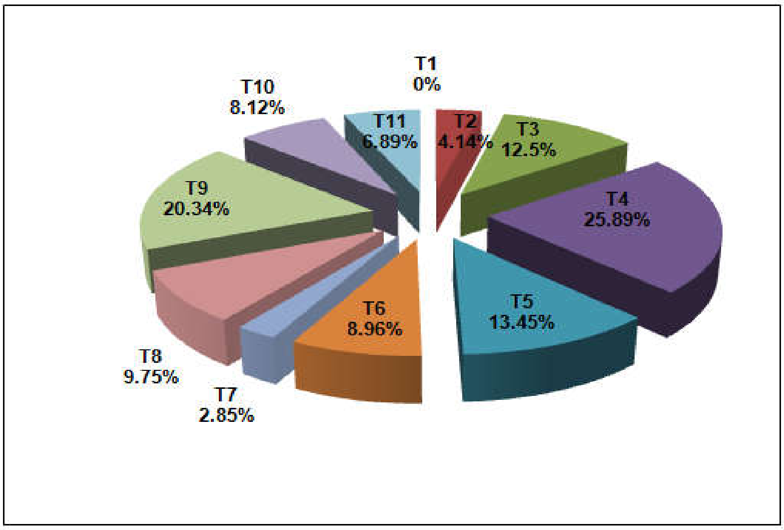

Figure 2. Effect of putrescine and IBA on per cent increase in yield in soybean

Leaf phosphorus content

Phosphorus is an important constituent of protoplasm and nucleic acid and protein also, it is essential for the formation of seed. Data pertaining to phosphorus content in leaves were estimated at four stages of observations i.e. 30, 45,6 0 and 75 DAS. Phosphorus has been recognized as an important environmental factor limiting crop growth and production. Significant results were recorded at all the stages of observations viz., 45, 60 and 75 DAS except 30 DAS. Data are presented in Table 1.

At 45 DAS significantly more leaf phosphorus content was recorded in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) when compared with treatment T_1 (control) and other remaining treatments under study. Treatment T_5 (125 ppm putrescine) also showed their significance over treatment T_1 (control). While, remaining treatments were found at par with treatment T_1 (control). The range of phosphorus content at 45 DAS in soybean was 0.39-0.54 %.

At 60 and 75 DAS significantly maximum leaf phosphorus content was recorded in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine) and T_8 (75 ppm IBA) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. While, rest of the treatments were found at par with treatment T_1 (control). The range of phosphorus content at 60 and 75 DAS in soybean was 0.59-0.77% and 0.44-0.60% respectively. The interference drawn from the data, it is clear that leaf phosphorus content was gradually increased upto 60 DAS and reduced thereafter at 75 DAS.

The increase in phosphorus content might be because of translocation of leaf phosphorus and it's utilization for development of food storage organ.Application of putrescine or IBA increased enzymatic activity and translocation processes from leaves to seeds, linking or converting to other plant metabolites. These might be the reasons for increase in leaf phosphorus content in the present investigation by the application of putrescine and IBA.

Amin *et al*. (2013) tested two plant growth regulators viz., putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1}, applied either alone or in combinations. Spraying of putrescine and IBA @ 100 mg l^{-1} significantly enhanced phosphorus content of chickpea (*Cicer arientinum* L.).

Leaf potassium content

Potassium is an essential macronutrient for plants involved in many physiological processes. It is important for crop yield as well as for the quality of edible parts of crops. Although K is not assimilated into organic matter, K deficiency has a strong impact on plant metabolism. Plant responses to low K involve changes in the concentrations of many metabolites as well as alteration in the transcriptional levels of many genes and in the activity of many enzymes. Data pertaining to potassium content in leaves were estimated at various stages of observations viz., 30, 45, 60 and 75 DAS. Significant results were recorded at all the stages of observations viz., 45, 60 and 75 DAS except 30 DAS. Data are presented in Table 1. At 45 DAS significantly maximum leaf potassium content was observed in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine), T_8 (75 ppm IBA) and T_5 (125 ppm putrescine) in a descending manner when compared with treatment T_1 (control). Remaining treatments under study were found at par with treatment T_1 (control). The range of potassium content at 45 DAS in soybean was 1.18-1.51%.

At 60 DAS significantly maximum leaf potassium content was observed in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study. At 75 DAS significantly maximum leaf potassium content was observed in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine), T_8 (75 ppm IBA), T_5 (125 ppm putrescine) and T_{10} (125 ppm IBA) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. While, rest of the treatments were found at par with treatment T_1 (control) at both the stages of observation. At 60 and 75 DAS the range of potassium content in soybean was 2.10-2.40% and 1.31-1.87% respectively.

It is clear from the data that leaf potassium content was increased gradually upto 60 DAS and decreased at 75 DAS. It might be because of diversion of potassium towards developing parts i.e. pods of the soybean crop at advanced stage. Application of putrescine or IBA increased enzymatic activity and translocation processes from leaves to seeds, linking or converting to other plant metabolites (Amin *et al*., 2013). These might be the reasons for increase in leaf potassium content in the present investigation by the application of putrescine and IBA. El-Bassiouny *et al*. (2008) tried arginine and putrescine (0.0, 0.6, 1.25, 2.5 and 5 mM) at three physiological stages (vegetative, 30 DAS; just before emergence of main spike, 60 DAS and during grain filling, 90 DAS) and found that foliar application of 2.5 mM arginine and putrescine on wheat significantly increased potassium. Amin *et al*. (2013) tested two plant growth regulators i.e. putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1}, applied either alone or in combinations. Spraying of putrescine and IBA @ 100 mg l^{-1} significantly enhanced potassium content of chickpea (*Cicer arientinum* L.).

Leaf chlorophyll content

Chlorophyll is a green pigment present in chloroplast of all green plant cells and tissues. These are essential photosynthetic pigments capable of absorbing light energy for the synthesis of carbohydrates. Chlorophyll content of the plant tissue represents the photosynthetic capacity of the plant. The treatment effects were found statistically significant at 45, 60 and 75 DAS stages of observations except 30 DAS. Data regarding leaf chlorophyll content in leaves of soybean are presented in Table 2. Data indicated that, at 45 DAS chlorophyll content was significantly increased in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_8 (75 ppm IBA) when compared with treatment T_1 (control). Remaining treatments were found at par with control. The range of chlorophyll content at 45 DAS in soybean was 1.72 - 2.03 mg g^{-1}. The per cent increase in chlorophyll content at 45 DAS in treatment T_4 (200 ppm putrescine) over T_1 (control) was 18.02.

At 60 and 75 DAS the treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) noted significantly maximum chlorophyll content over treatment T_1 (control) and rest of the treatments under study. Remaining treatments were found at par with treatment T_1 (control). The range of chlorophyll content at 60 DAS and 75 DAS in soybean was 2.02 - 2.23 mg g^{-1} and 1.99 - 2.21 mg g^{-1} respectively. The per cent increase in chlorophyll content at 60 DAS and 75 DAS in treatment T_4 (100 ppm putrescine) over T_1 (control) was 10.39 and 11.05 respectively. Putrescine or IBA treatments might retard chlorophyll destruction and increase their biosynthesis or stabilize the thylakoid membrane. Polyamines may retard senescence and chlorophyll loss by altering the stability and permeability of membranes and protecting chloroplast from senescing (Gonzalez-Aguilar *et al*., 1997).

These might be the reasons for increase in leaf chlorophyll content by the application of putrescine and IBA. Shraiy and Hegazi (2009) conducted an experiment to study the effect of acetyl salicylic acid (ASA) @ 10 and 20 ppm, indole-3-bytric acid (IBA) @ 50 and 100 ppm and gibberellic acid (GA) @ 50 and 100 ppm on pea (*Pisum sativum* L.). Application of ASA and IBA at 25 and 35 DAS significantly increased total chlorophyll in leaves. Ahmed *et al*. (2013) conducted a field experiment to study the effect of putrescine (0, 1 and 2 ppm) and humic acid (0, 1 and 2 %) were sprayed eight times started at 45 DAP and repeated every after 15 days on cotton and reported that foliar application of 2 ppm putrescine and 1% humic acid significantly enhanced chlorophyll content.

Protein content in seed

Protein content in seed is one of the considerable factor for seed quality determination. The Table 2 gives detail data on protein content. Data indicated that protein content was significantly increased in treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) when compared with treatment T_1 (control) and remaining treatment under study. While treatments T_8 (75 ppm IBA), T_5 (125 ppm putrescine), T_{10} (125 ppm IBA), T_6 (150 ppm putrescine), T_2 (50 ppm putrescine), T_{11} (150 ppm IBA) and T_7 (50 ppm IBA) were found at par with treatment T_1 (control).

Foliar application of putrescine and IBA increased seed protein content in the present investigation might be due to more enzymatic activity and translocation processes from leaves to seeds and linking or conversion of other plant metabolites (Amin, 2013). Shraiy and Hegazi (2009) conducted an experiment to study the effect of acetylsalicylic acid (ASA) @ 10 and 20 ppm, indole-3-bytric acid (IBA) @ 50 and 100 ppm and gibberellic acid (GA) @ 50 and 100 ppm on pea (*Pisum sativum* L.). Application of ASA and IBA at 25 and 35 DAS significantly increased protein content. Mathur and Vyas (2007) conducted an experiment to study the effect of salicylic acid (1, 2 and 3 mM), sitosterol as well as putrescine concentrations (0.05, 0.10 and 0.15 mM) on pearl millet (*Pennisetum typhoides*). Results showed that application of salicylic acid at 3 mM and sitosterol or putrescine at 0.15 mM significantly increased crude protein.

Oil content in seed

Soybean is mainly known as oilseed crop and oil percentage in seed is one of the important aspect in quality of grain. The data regarding oil content in seed are given Table 2. Maximum oil content in seed of soybean was recorded in the treatment T_4 (100 ppm putrescine) followed by the treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and remaining treatments under study. The treatments T_5 (125 ppm putrescine), T_6 (150 ppm putrescine), T_2 (50 ppm putrescine), T_{10} (125 ppm IBA), T_{11} (150 ppm IBA) and T_7 (50 ppm IBA) were found at par with treatment T_1 (control).

Data revealed that, foliar application of 100 ppm putrescine stood first in oil content in seeds of soybean. Oil content in soybean seed recorded in treatment T_1 (control) was 19.81 % and in treatment T_4 (100 ppm putrescine) was 22.75 %. It appeared from the results that putrescine or IBA are more effective on seed oil content. This might be due to enhancement of enzymatic activity and translocation of metabolites to the soybean seeds. Mathur and Vyas (2007) conducted an experiment to study the effect of salicylic acid (1, 2 and 3 mM), sitosterol as well as putrescine concentrations (0.05, 0.10 and 0.15 mM) on pearl millet (*Pennisetum typhoides*). Results showed that application of salicylic acid at 3 mM and sitosterol or putrescine at 0.15 mM significantly increased oil content.

Yield and yield contributing parameters

Seed yield, and its related parameters in soybean were influenced by the application of growth regulator which have different influence on the allocation of assimilates between vegetative and reproductive organs. In general crop yield depends on the accumulation of photo-assimilates during the growing period and the way, they are partitioned between desired storage organ of plant. In present study, data revealed that the application of plant growth regulators significantly increased, number of pods plant^{-1}, 100 seed weight and finally seed yield determining components in soybean.

Number of pods plant^{-1}

The data with respect to number of pods plant^{-1} are presented in Table 3. Data indicates that all the treatments were statistically significant over control. Number of pods plant^{-1} were significantly increased in treatment T_4 (100 ppm putrescine) followed by treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine) and T_5 (125 ppm putrescine) in a descending manner when compared with remaining treatments and treatment T_1 (control). Treatments T_8 (75 ppm IBA) and T_{10} (125 ppm IBA) also showed their significance over treatment T_1 (control). While, treatments T_6 (150 ppm putrescine), T_{11} (150 ppm IBA), T_2 (50 ppm putrescine), and T_7 (50 ppm IBA) were found at par with T_1 (control).

Thavaprakash *et al*. (2006) conducted an experiment to study the effect of plant growth promoters on assimilate partitioning and seed yield of green gram. The results revealed that foliar application of putrescine and spermine @ 20 ppm registered significant increase in yield attributing characters such as numbers of pods plant^{-1} over control. Shraiy and Hegazi (2009) studied the effect of acetylsalicylic acid (ASA) @ 10 and 20 ppm, indole-3-bytric acid (IBA) @ 50 and 100 ppm and gibberellic acid (GA) @ 50 and 100 ppm on pea (*Pisum sativum* L.). Application of ASA and IBA at 25 and 35 DAS significantly increased number of pods plant^{-1}. Amin *et al.* (2013) studied the effect of two plant growth regulators putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1} applied either alone or in combinations. Spraying of putrescine and IBA @ 100 mg l^{-1} significantly increased number of pods of chickpea (*Cicer arientinum*).

100 seeds weight

Data regarding 100 seed weight showed significant variation and are given in Table 3. It was observed that foliar application of 100 ppm putrescine gave significantly higher 100 seed weight when compared with treatment T_1 (control) and remaining treatments under study. The range of increase in seed weight was 8.61 g in control (T_1) to 11.69 g in treatment receiving 100 ppm putrescine (T_4). 100 seed weight was also significantly increased in treatment receiving 100 ppm putrescine followed by treatments T_9 (100 ppm IBA) and T_3 (75 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study. Treatments T_5 (125 ppm putrescine), T_8 (75 ppm IBA), T_{10} (125 ppm IBA), T_7 (50 ppm IBA), T_{11} (150 ppm IBA), T_6 (150 ppm putrescine) and T_2 (50 ppm putrescine) also showed their significance over treatment T_1 (control). El-Bassiouny *et al.* (2008) tested arginine and putrescine (0.0, 0.6, 1.25, 2.5 and 5 mM) at three physiological stages (vegetative, 30 DAS; just before emergence of main spike, 60 DAS and during grain filling, 90 DAS) and reported that foliar application of 2.5 mM arginine and putrescine on wheat significantly increased 1000 grains weight over control.

Shraiy and Hegazi (2009) studied the effect of acetylsalicylic acid (ASA) @ 10 and 20 ppm, indole-3-bytric acid (IBA) @ 50 and 100 ppm and gibberellic acid (GA) @ 50 and 100 ppm on pea (*Pisum sativum* L.). Application of ASA and IBA at 25 and 35 DAS significantly increased 1000 seeds weight over control.

Seed yield ha^{-1}(q)

Data regarding seed yield ha^{-1} are given in Table 3 and figure 1 and 2 respectively. Seed yield is a complex physiological character which is the sum total of all metabolic activities taking place in plant body. Seed yield and its related parameters were influenced by the application of different growth regulators in soybean which indicated that these chemicals have differential influence on the allocation of assimilates between vegetative and reproductive organs. In general, crop yield depends on the accumulation of photo-assimilates during the growing period and the way they are partitioned between desired storage organs of plant. In the present study, it is revealed that the application of PGRs significantly increased the number of pods, 100-seed weight and finally seed yield hectare^{-1} which are the most important yield determining components in soybean.

The maximum seed yield hectare^{-1} was recorded in treatment T_4 (100 ppm putrescine). The range of increase in seed yield hectare^{-1} was 17.84 q in treatment T_1 (control) to 22.46 q in treatment T_4 (100 ppm putrescine) respectively. Significantly maximum seed yield ha^{-1} were recorded in treatment T_4 (100 ppm putrescine) when compared with control and remaining treatments under study. Next to this treatment, treatments T_9 (100 ppm IBA), T_3 (75 ppm putrescine), T_5 (125 ppm putrescine), T_8 (75 ppm IBA), T_6 (150 ppm putrescine), T_{10} (125 ppm IBA), T_{11} (150 ppm IBA) and T_2 (50 ppm putrescine) also gave maximum seed yield ha^{-1} when compared with treatment T_1 (control). While, treatment T_7 (50 ppm IBA) was found at par with T_1 (control). The highest per cent increase in yield ha^{-1} over control was observed in treatment sprayed with 100 ppm putrescine (25.89 %) and 100 ppm (20.34%) over control.

Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crops. Growth regulators can improve the physiological efficiency including photosynthetic ability and enhance the effective partitioning of accumulates from source and sink in the field crops (Solamani *et al*., 2001). The diamine putrescine occurred widely in the higher plants. It was suggested to be involved in a variety of growth and developmental processes such as cell division (Bueno and Matilla,1992), fruit set and growth (Biasi e*t al*.,1991) and senescence (Kao,1994).The interaction of polyamines with the macromolecules was responsible for physiological effects on plant growth and development (Smith,1985). Growth regulator IBA is proved to improve effective partitioning and translocation of accumulates from source to sink in the field crops. The plant growth regulators also increases mobilization of reserve food materials to the developing sink through increases in hydrolyzing and oxidizing enzyme activities and lead to yield increases. IBA increases the ability of cell division in meristematic zones of plant and hence increases the ability of plant to absorb nutritive material which finally lead to the increase of grain yield (Ghodrat *et al*., 2012).

The increase in the yield recorded in this investigation could be a reflection of the effect of growth regulators on NPK which gave a chance to the plant to carry more seed and marked increase in the photosynthetic pigments content which could lead to increase in photosynthesis, resulting in greater transfer of assimilates to the seeds and causing increase in their weight. Thavaprakash *et al*. (2006) conducted an experiment to study the effect of plant growth promoters on assimilate partitioning and seed yield of green gram. The results revealed that foliar application of putrescine and spermine @ 20 ppm registered significant increase in yield attributing characters such as numbers of flowers plant^{-1}, number of pods plant^{-1}, fertility coefficient, number of filled seeds pod^{-1} and per cent filled seeds over control. Field experiment was conducted by Mathur and Vyas (2007) to estimate the effect of salicylic acid (1, 2 and 3 mM), sitosterol as well as putrescine concentrations (0.05, 0.10 and 0.15 mM) on pearl millet (*Pennisetum typhoides*). Results showed that application of salicylic acid @ 3 mM and sitosterol or putrescine @ 0.15 mM significantly increased yield and its components i.e. ear length, ear diameter, grain yield plant^{-1}, crop index and 100- grain weight over control. Amin *et al*. (2013) studied the effect of two plant growth regulators putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1} applied either alone or in combinations. Spraying of putrescine and IBA @ 100 mg l^{-1} significantly increased number of pods, seed yield, straw and biological yield feed^{-1} of chickpea (*Cicer arientinum*).

From overall results, it can be stated that foliar application of growth regulators such as putrescine and IBA with different concentrations improved the chemical, biochemical, yield and yield contributing parameters might have helped in attaining better seed yield in the present investigation. From the present study, it can be inferred that foliar application of 100 ppm putrescine followed by 100 ppm IBA at two stages i.e. before flowering (30DAS) and 10 days after flowering (45DAS) significantly enhanced the chemical, biochemical, yield and yield contributing parameters and ultimately increased the yield by 25.89 followed by 20.34 per cent respectively over control in soybean.

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