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ROLE OF PUTRESCINE AND INDOLE-3-BUTYRIC ACID IN IMPROVING MORPHO-PHYSIOLOGICAL PARAMETERS AND PRODUCTIVITY OF GROUNDNUT

Reshma D.Shinde[1], R. D. Deotale[2] and G. N. Jadhav[3]

ABSTRACT

Field experiment was conducted with different concentrations of putrescine and Indole-3-butyric acid (25 ppm, 50 ppm, 75 ppm, 100 ppm) during *kharif* season of 2016-17 at Botany Section College of Agriculture, Nagpur to evaluate the morpho-physiological parameters, yield and economics of groundnut. Observations on height plant, number of secondary branches, leaf area, dry weight of plant, RGR, NAR, yield ha^{-1},harvest index were recorded. B:C ratio was also calculated. Different concentrations of putrescine and Indole-3-butyric acid gave significant variation. But two foliar sprays of 100 ppm IBA at 20 and 35 DAS stood first in rank and significantly enhanced all above mentioned parametes. Treatment T_6 (25 ppm IBA) gave the highest B : C ratio of 2.78 as compared to 2.69 in control.

(Key words: Groundnut, putrescine, Indole-3-butric acid, foliar spray, mopho physiological parameters)

INTRODUCTION

Groundnut 'the unpredictable legume' has originated in Brazil and South America. The botanical name of groundnut *Arachis hypogea* (L.) is derived from Greek word "Arachis" meaning a legume and "hypogea" meaning below ground referring to geographic nature of pod formation.Groundnut belongs to family leguminaceae, genes Arachis and has chromosome number 2n=40. It is also a day neutral plant, flowers are self pollinated. Groundnut is one of the leading field legume in India. Being an oilseed crop it plays an important role in country's agricultural economy, on account of its versatile use in domestic and industrial fields. Domestically it is used as a source of edible and cattle feed etc. It has greater importance in industry as it is one of the main source of raw material for vanaspati industries in India, unlike some of western countries where other edible oils are mainly used for hydrogenation.

India ranks second in production of groundnut after China. In India area under groundnut crop during 2015-16 was 66 million hectares with the production of 47 million tonnes having potentiality of yield was 1400 kg ha^{-1} (Anonymous 2016 a). In Maharashtra total area under groundnut cultivation during 2015-16 was 30.9 million hectares, with the production of 33.4 million tonnes having average productivity of 1078 kg ha^{-1} (Anonymous , 2016 b). 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 e*t 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. Considering the above facts present investigation was undertaken to study the role of putrescine and IBA of groundnut.

MATERIALS AND METHODS

Seeds of groundnut cultivar AK-303 were collected from Dr. PDKV, Akola The field experiment was laid out in Randomized Block Design (RBD) with three replications consisting of nine treatments comprising of different doses of putrescine and IBA (25 ppm, 50 ppm, 75 ppm, 100 ppm).Seeds were sown at the rate of 100 to 125 kg ha^{-1} by dibbling method at a spacing of 45 cm x 10 cm. Data were recorded for plant height, leaf area, dry weight of plant at 20, 35, 50 and 65 DAS and number of secondary branches

1 and 3 P.G. Students, Botany Section, College of Agriculture, Nagpur
2. Professor, Botany Section, College of Agriculture, Nagpur

was recorded at harvest. Pod yield ha^{-1} (q), harvest index (%) and B:C ratio were also recorded and calculated. The analysis of variance was performed to test the significance of differences between the treatment for all the characters as per the methodology suggested by Panse and Sukhatme (1954).

RESULTS AND DISCUSSION

Plant height (cm)

Data regarding plant height were recorded at 20, 35, 50 and 65 DAS and subjected to statistical analysis. The data are presented in table 1.

Data in table, show significant increase in plant height under the effect of combination of different concentrations of putrescine and IBA when compared with control plants. Only at 20 DAS the data regarding plant height was found non significant, because foliar sprays of putrescine and IBA were given from this stage onwards (20 DAS).

At 35 DAS plant height was recorded significantly maximum in treatment T_9 (100 ppm IBA) followed by treatment T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study.

At 50 DAS significantly highest plant height was recorded in treatment T_9 (100 ppm IBA) followed by the treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and rest of the treatments.

At 65 DAS significantly maximum plant height was registered in treatment T_9 (100 ppm IBA) followed by treatment T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and rest of the treatments. Treatments T_8 (75 ppm IBA), T_4 (75 ppm putrescine), T_3 (50 ppm putrescine) and T_7 (50 ppm IBA) also increased plant height significantly as compared to control and remaining treatments under study.

Due to foliar spray of putrescine and IBA at concentrations of 100 ppm exhibited best result among all the treatments. The range of plant height at 65 DAS was 25.24 cm (control) to 32.11 cm (100 ppm) IBA.

Putrescine increased the growth characters viz., plant height and number of leaves. Vegetative plant growth is controlled by interaction of multiple regulatory factors (enzymes, metabolites, hormones etc.) and that the effect of interaction may change with the stage of plant development (Loomis *et al*., 1979). In groundnut putrescine application may act as source of nitrogen which leads to increase RNA and DNA production. This enhanced production of RNA and DNA leads to increase cell division. At lower concentrations, it is comparable to that of endogenous promoters like auxins, cytokinins and gibberllins which stimulates growth by increasing these promoters (Mulkey, 1982).

Similarly, IBA is a synthetic auxin. Auxins are used commercially for enhancing crop production and regulation of plant growth and development such as shoot tissue, young leaves and developing grains. It is also found promotive in lateral root development (Nagel, 2001). These might be the reasons for increased plant height in the present investigation by the application of putrescine and IBA.

The above observations are similar with the findings of Wagh (2015).He formulated the experiment to study the effect of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125 and 150 ppm on soybean and reported that, two foliar sprays of putrescine and IBA @ 100 ppm significantly increased plant height over control.

Ahmed *et al*. (2013) tried a field experiment to determine the effect of growth regulators on cotton. Experiment comprised of 3 levels of putrescine viz., 0, 1 and 2 ppm, three levels of IBA viz., 1, 2 and 3 ppm and three levels of humic acid viz., 0, 1 and 2%, were sprayed eight times started at 45 DAP and repeated every after 15 days on cotton. Results indicated that foliar application of 2 ppm putrescine and 1% humic acid significantly increased plant height over control.

Number of secondary branches $plant^{-1}$

Number of secondary branches $plant^{-1}$ was counted at harvest. The branches originating from primary branches were taken as secondary branches.

Data regarding number of secondary branches $plant^{-1}$ was recorded at harvest. The data are presented in table1.

At harvest the data recorded about number of secondary branches $plant^{-1}$ were statistically significant. At harvest range of number of secondary branches $plant^{-1}$ recorded was 8.87-11.66. The significantly highest number of secondary branches $plant^{-1}$ was recorded in treatment T_9 (100 ppm IBA) followed by the treatment T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and rest of the treatments under study. Similarly treatments T_8 (75 ppm IBA), T_4 (75 ppm putrescine), T_3 (50 ppm putrescine) and T_7 (50 ppm IBA) were significantly gave maximum branches over control and with other treatments under study. Treatments T_2 (25 putrescine) and T_6 (25 ppm IBA) were found at par with treatment T_1 (control).

It was clear from above data that foliar application of growth regulators putrescine and IBA increased number of secondary branches $plant^{-1}$. Similar results were also obtained by Ahmed *et al*. (2013).They conducted a field experiment to determine the effect of growth regulators on cotton. Experiment comprised of 3 levels of putrescine viz., 0, 1 and 2 ppm, three levels of IBA viz., 1, 2 and 3 ppm and three levels of humic acid viz., 0, 1 and 2%, were sprayed eight times started at 45 DAP and repeated every after 15 days on cotton. Results indicated that foliar application of 2 ppm putrescine and 1% humic acid significantly increased the number of fruiting branches significantly.

Leaf area of plant

The data regarding the leaf area at 20, 35, 50 and 65 DAS are furnished in table 1.

All the treatments under study were found significantly superior to each other. Data revealed that the leaf area increased from 20 to 65 DAS. The leaf area at 20 DAS was seen non significant from the observations because foliar sprays of hormones were given from this stage onwards (20-25 DAS).

From table1 it was observed that at 35 DAS significantly maximum leaf area was noticed in treatment T_9 (100 ppm IBA) followed by treatment T_5 (100 ppm putrescine) when compared with control and rest of the treatments under study. Treatments T_8 (75 ppm IBA) and T_4 (75 ppm putrescine) also increased leaf area significantly over control and rest of the treatments under study. Significantly lower leaf area was noticed in treatments T_3 (50 ppm putrescine), T_7 (50 ppm IBA), T_6 (25 ppm IBA) and T_2 (25 ppm putrescine) and were found at par with each other.

At 50 DAS significantly maximum leaf area was recorded in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with control and rest of the treatments.

At 65 DAS treatment T_9 (100 ppm IBA) exhibited significantly maximum leaf area followed by treatment T_5 (100 ppm putrescine) when compared with control and rest of the treatments. Treatment T_8 (75 ppm IBA) showed significantly maximum leaf area when compared with treatment T_1 (control) and remaining treatments under study.

Leaf area plant^{-1} was 1.159 dm^2 in control to 1.38 dm^2 in treatment receiving 100 ppm IBA at 20 DAS, 1.82 to 2.12 dm^2 at 35 DAS, 3.81 to 4.23 dm^2 at 50 DAS and 4.04 to 5.11 dm^2 at 65 DAS respectively.

Hence, it can be concluded that when growth regulators applied through foliar spray, might have accelerated the metabolic and physiological activities of the plant and put up more growth by assimilating more amount of major nutrients and ultimately increased the leaf area plant^{-1} in the present investigation.

Putrescine increased the growth character viz., leaf area. This increased growth in groundnut due to polyamine application implied that they could act as a growth promoter. Putrescine could act as a source of nitrogen (Mirza and Bagni, 1991). At lower concentrations it is comparable to that auxin (Mulkey *et al*., 1982) and ethylene (Estellie and Somervillie, 1987; Gifford and Evans, 1981). It can also induce the synthesis of RNase enzyme, which enhances the 'N' use efficiency (Bagni *et al*., 1981). Similarly IBA enhances cell division and chlorophyll accumulation and in turn reflects on the increase in vegetative growth (Amin *et al*., 2007). This might be the reasons for increase in leaf area in the present investigation. Physiological role of putrescine and IBA was also documented by several scientists.

Wagh (2015) revealed the effect of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125, 150 ppm on soybean and reported that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased leaf area.

Bideshki *et al*. (2013) conducted a field experiment to study the impact of 0 and 100 ppm indole-3-butyric acid (IBA) and 0, 0.1 and 0.5mM salicylic acid (SA) on garlic and reported that 0.5 mM salicylic acid and 100 ppm IBA significantly enhanced leaf area.

Dry weight of plant

Data regarding total dry matter production were recorded at the four different growth stages i.e. 20, 35, 50 and 65 DAS and are presented in table 6 and figure 7. Data on dry matter production exhibited significant variation at 35, 50 and 65 DAS.

There was an increase in total dry weight with an advancement of crop growth and maximum total dry matter production was observed at 65 DAS. It was observed that treatments differed significantly at all stages except at 20 DAS, because foliar sprays of growth regulators of different concentrations were given from this stage onwards (20 and 35 DAS).

Significant and gradual increase (35-50 DAS) was noticed regarding dry matter production at different stages of observations. The data recorded about dry matter production was subjected to statistical analysis and found significant.

From the table at 35 DAS significantly maximum dry matter was reported in treatment T_9 (100 ppm IBA) followed by treatment T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study.

At 50 DAS significantly increase in dry matter was recorded in treatment T_9 (100 ppm IBA) followed by the treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and remaining treatments under study. Furthermore, treatments T_4 (75 ppm putrescine) and T_3 (50 ppm putrescine) also significantly increased dry matter over treatment T_1 (control).

It was observed that, at 65 DAS significantly more dry matter was accumulated in treatment T_9 (100 ppm IBA) followed by the treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and remaining treatments under study.

From the data it is cleared that dry matter increased gradually from 35-50 DAS. Dry matter accumulation is a function of leaf area and maximum leaf area was observed during 50-65 DAS and it is period of maximum photosynthesis and yielded maximum dry matter production. Biomass (dry matter gain) in crop plants is controlled by complex interaction of photo assimilates production by source leaves and photosynthates utilization by sink tissues (Patrick, 1988). The high dry matter accumulation and allied growth characters might be due to increased chlorophyll content. Ability of particular crop plant to carryout photosynthesis during growth period determines dry matter accumulation and even final yield of plant. Phloem transport process will be of equal importance for this and it determines that how effectively nutrients are made available to plant parts.

It was suggested that putrescine improves the photosynthetic rate and stomatal conductance and putrescine also seems to be helpful in ameliorate the negative effect of K^+ and Cl^- on photosynthesis by reducing uptake of these two and improvement in concentration of K^+ and Ca^{+2} ions. Putrescine (polyamines) application implied that they could act as a growth promoter (Mirza and Bagni, 1991). Similarly, dry matter production by the application of IBA might be due to enhancement of cell division and chlorophyll accumulation (Amin *et al*., 2007). These might be the reasons for increase in dry weight of groundnut plants due to application of putrescine and IBA in the present investigation.

Similar, results were also noted by Shallan *et al.* (2012). They conducted field experiment to investigate the effect of sodium nitroprusside (SNP), putrescine and glycine betaine (GB) on cotton plant. Treatments comprised of three levels of SNP *viz*., 0.05, 0.1 and 1 mM, putrescine and GB viz., 200, 400 and 600 ppm. The results showed that 0.05 mM SNP, 600 ppm putrescine and 800 ppm GB enhanced the dry weight of plant.

Moreover, Shraiy *et al.* (2009) explained the effect of acetylsalicylic acid (ASA) @ 10 and 20 ppm, indole-3-butyric 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 enhanced dry weight. Wagh (2015) also studied the effect of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125 and 150 ppm on soybean. He inferred that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased dry weight.

Growth analysis

Growth analysis is one of the measures for accessing the seed yield of plant. The physiological basis of yield difference can measured through an evaluation of difference in growth parameters and their impact on yield. The productivity of crop may be related with the parameters such as RGR, NAR and partitioning of total photosynthate into economic and non-economic sink. The analyzed data of RGR and NAR are presented in table 7 and graphically interpreted in table 2.

Relative growth rate

The highest rate of RGR indicates the ability of maximum dry matter for development. The increment in RGR might be associated with maximum leaf area expansion and growth of stem and root. Increment in NAR is related with the increase in total dry weight of plant unit^{-1} of leaf area.

Data regarding RGR are given in table 2.

Considering all the treatments under study, significantly maximum RGR was recorded in treatment T_9 (100 ppm IBA) i.e., 0.0760 g g^{-1}day^{-1} at 20-35 DAS, 0.0452 g g^{-1}day^{-1} at 35-50 DAS and 0.0227 g g^{-1}day^{-1} at 50-65 DAS respectively. But it was lowest in control i.e., 0.0735 g g^{-1}day^{-1} at 20-35 DAS, 0.0400 g g^{-1}day^{-1} at 35-50 DAS and 0.0209 g g^{-1}day^{-1} at 50-65 DAS respectively.

At first stage i.e. 20-35 DAS range of RGR was 0.0735–0.0760 g g^{-1} day^{-1}. At second stage i.e. 35-50 DAS range of RGR was 0.0400-0.0452 g g^{-1} day^{-1}. At both the stages significantly maximum RGR was observed in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and remaining treatments under study.

At third stage i.e. 50-65 DAS range of RGR recorded was 0.0209-0.0227 g g^{-1} day^{-1}. Significantly maximum RGR was observed in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine), T_8 (75 ppm IBA) and T_4 (75 ppm putrescine) when compared with control (T_1).

The effect of putrescine and IBA on RGR was in agreement with Wagh (2015), who mention that two foliar sprays (30 and 45 DAS) of 100 ppm putrescine and IBA was found more effective and significantly increased the RGR and NAR of soybean plant.

Net assimilation rate

Net assimilation rate (NAR), synonymously called as unit leaf rate expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface area (Gregory, 1926). Increase in NAR during reproductive phase might be due to increase efficiency of leaves for photosynthesis as a response to photosynthetic apparatus to increase demand for assimilates by growing seed fraction and also due to photosynthetic contribution by pod and sink demand on photosynthetic rate of leaves.

Considering all the treatments under study, significantly maximum NAR was recorded in treatment with 100 ppm IBA (T_9) i.e. 0.1141 g dm^{-2} day^{-1} at 20-35 DAS, 0.0862 g dm^{-2} day^{-1} at 35-50 DAS and 0.0476 g dm^{-2} day^{-1} at 60-75 DAS respectively. But it was lowest in control i.e. 0.1048 g dm^{-2} day^{-1} at 20-35 DAS, 0.0706 g dm^{-2} day^{-1} at 35-50 DAS and 0.0403 at 50-65 DAS respectively.

As per the observations at first stage i.e. 20-35 DAS range of NAR recorded was 0.1048-1141 g dm^{-2} day^{-1}. At second stage the range of NAR recorded at second stage i.e. 35-50 DAS was 0.0706-0.0862 g dm^{-2} day^{-1}. At both stages significantly maximum NAR was calculated in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine), T_8 (75ppm IBA) and T_4 (75 ppm putrescine) when compared with treatment T_1 (control) and other treatments under study.

At third stage i.e. 50-65 DAS range of NAR recorded was 0.0403-0.0476 g dm^{-2} day^{-1}. Significantly maximum NAR was observed in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA), and in a descending manner over control (T_1).

Mathur and Vyas (2007) were conducted a field 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 @ 3 mM and sitosterol or putrescine @ 0.15 mM significantly increased net assimilation rate.

Wagh (2015) executed an experiment to study the effect of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125 and 150 ppm on soybean. He reported that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased RGR and NAR.

Yield parameters

Seed yield is the economic yield which is final result of physiological activities of plant. Economic yield is the part of biomass that is converted into economic product. (Nichiporovic,1960).

Seed yield is influenced by morpho-physiological parameters such as plant height, total dry matter production, leaf area and number of secondary branches, which are considered as yield contributing parameters. Seed yield ha^{-1} are combined effect of yield attributing characters and physiological efficiency of plant during the present investigation.

Source-sink relation contributes to the seed / grain yield. It includes phloem loading at source (leaf) and unloading at sink (seed and fruit) by which the economic part will be getting the assimilates synthesized by photosynthesis. Partitioning of the assimilate in the plant during reproductive development is important for flower, fruit and seeds. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (harvest index) or both (Gardner *et al*., 1988).

The maximum pod yield ha^{-1} was significantly maximum in treatment T_9 (100 ppm IBA) followed by treatments T_5 (100 ppm putrescine) and T_8 (75 ppm IBA) when compared with treatment T_1 (control) and rest of the treatments. Treatments T_4 (75 ppm putrescine) and T_3 (50 ppm putrescine) were also found significantly superior over treatment T_1 (control).

The increase in yield and yield attributes may be due to altering the hormonal balance and improved water relation in plants. PA namely putrescine is involve in stabilization of D_1 and D_2 polypeptides of photosystem second which is the source of electron for $NADP^+$ reduction at photosysytem one (Taiz and Zeiger, 1991). It is also prevented the lipid peroxidation, proteolytic attack and inhibitors of ethylene synthesis through inhibition of ACC synthase and conversion of ACC to ethylene, which is a common phenomenon occurred during senescence. The present results also in line with the report of Kabir *et al.* (1992). They stated that PAs improved the yield and yield attributes in tomato. The increments in yield components due to putrescine treatments may be attributed to the increasing growth rate, in this respect, Davies (1995) reported that polyamines play a critical role in different biological processes, including cell division, growth, somatic embryogenesis, floral initiation, development of flowers and fruits. It is worthy to mention that there is a close relationship between the effect of PAs and the stimulated growth, endogenous phytohormones, the photosynthetic output (soluble sugars, polysaccharides and total carbohydrates) and the nitrogen constituents. These results might increase the efficiency of solar energy conversion which maximize the growth ability of groundnut plant and consequently increased its productivity and yield components.

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 increase in hydrolyzing and oxidizing enzyme activities and lead to increase in yield. 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 leads to the increase in 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 putrescine and IBA on growth and development. It might also be due to marked increase in plant height, leaf area and dry weight which gave a chance to the plant to carry more grain and marked increase in the photosynthetic pigments content which could lead to increase in photosynthesis, resulting in greater transfer of assimilates to the grains and causing increase in their weight. The above finding was in corroboration with the findings of Thavaprakash (2006) in green gram. The promotive effects of putrescine and IBA on the harvestable yields of groundnut indicated that the strengths (defined as sink size / sink activity) of reproductive parts are greatly increased, when compared with 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 1000 grain weight over control.

Amin *et al*. (2013) explained 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*).

Deotale *et al*. (2016) formulated the experiment to study the different concentrations of putrescine and IBA (50, 75, 100, 125 and 150 ppm each) with one control on yield and yield contributing characters of soybean and reported that two foliar sprays of 100 ppm putrescine and 100 ppm IBA at two stages i.e. before flowering and 10 days after flowering were found to be most effective in enhancing number of pods plant^{-1} and weight of 100 seeds significantly. Seed yield ha^{-1} was also increased significantly with the foliar sprays of 100 ppm putrescine (25.89%) and IBA (20.34%) over control.

Pinkey *et al*. (2016) carried out a field experiment to study the effect of putrescine in mitigating the water stress in wheat. The experiment consist of four water stress conditions and four rates of putrescine (control,10,50,100 ppm) with four replications by using split plot design. The result showed that foliar spray of putrescine @ 100 ppm resulted in significantly higher grain, straw and biological yield.

Harvest index

Data regarding harvest index were found statistically significant. Significantly maximum harvest index was recorded in treatment T_9 (100 ppm IBA) and minimum in control (T_1). The range of increased harvest index was 24.29% in treatment T_9 when compared to control (T_1) 20.51 per cent.

Similarly, harvest index was also significantly increased in treatment receiving T_9 (100 ppm IBA) followed by treatment T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study. Treatments T_8 (75 ppm IBA), T_4 (75 ppm putrescine), T_3 (50 ppm putrescine) and T_7 (50 ppm IBA) were also noted significantly more harvest index over control (T_1). Treatments T_6 (25 ppm IBA) and T_2 (25 ppm putrescine) were found at par with T_1 (control).

Pinkey *et al.* (2016) laid out a field experiment to study the effect of putrescine in mitigating the water stress in wheat. The result showed that foliar spray of putrescine @ 100 ppm resulted in significantly higher grain, straw and biological yield.

Harvest index is the proportion of biological yield represented by economic yield. It is the coefficient of effectiveness or migration coefficient. Harvest index reflects the proportion of assimilate distribution between the economic and total biomass (Donald and Hamblin, 1976). Increase in harvest index might be the result of co-ordinated interplay of growth and development characters.

The highest per cent increase in yield over control was observed in treatment 100 ppm IBA (T_9) i.e. 32.72 %. Next to this treatment, foliar spray of 100 ppm putrescine (T_5) also enhanced yield by 25.72 % over control. From overall results, it can be stated that foliar application of growth regulators such as putrescine and IBA with different concentrations improved the morpho-physiological, biochemical and yield and yield contributing parameters might have helped in attaining better pod yield in the present investigation.

Data in respect of B: C ratio are represented in table 2.

Finally it is inferred that, spraying plants at vegetative stage (20 and 35 DAS) with 25 ppm IBA having B:C ratio of 2.78 could be considered as the most suitable time and most suitable concentration to expect promising improvement regarding the growth parameters, physiological characters and yield of groundnut.

Table 1. Effect putrescine and Indole-3-butric acid on morpho-physiological parameters of groundnut

Treatments	Plant height (cm)				Number of secondary branches	Total dry weight (g)				Leaf area (dm^2)			
	20 DAS	35 DAS	50 DAS	65 DAS		20 DAS	35 DAS	50 DAS	65 DAS	20 DAS	35 DAS	50 DAS	65 DAS
T_1 (Control)	11.40	15.71	22.69	25.20	8.87	1.19	1.82	3.81	4.04	1.16	3.50	6.48	8.88
T_2 (25 ppm Putrescine)	10.42	16.78	23.14	27.90	9.56	1.33	1.90	3.84	4.17	1.33	3.71	6.87	9.43
T_3 (50 ppm Putrescine)	10.69	17.68	24.71	28.10	10.04	1.25	1.95	3.89	4.25	1.24	3.81	7.17	9.87
T_4 (75 ppm Putrescine)	9.92	18.05	26.91	28.80	10.21	1.15	1.96	3.99	4.35	1.20	3.84	7.46	10.23
T_5 (100 ppm Putrescine)	11.92	20.84	29.50	32.10	11.22	1.35	2.10	4.21	5.04	1.34	4.15	7.98	11.23
T_6 (25 ppm IBA)	10.39	15.76	22.72	25.90	8.99	1.26	1.84	3.83	4.15	1.21	3.59	6.56	8.98
T_7 (50 ppm IBA)	10.89	16.93	24.07	27.40	9.78	1.16	1.92	3.87	4.24	1.27	3.74	7.10	9.64
T_8 (75 ppm IBA)	11.92	18.80	27.83	30.30	10.44	1.20	1.97	4.00	4.42	1.28	3.96	7.81	10.46
T_9 (100 ppm IBA)	12.15	21.16	30.52	33.00	11.66	1.38	2.12	4.23	5.11	1.24	4.24	8.35	11.68
SE (m)±	0.19	0.901	1.282	0.71	0.203	0.017	0.038	0.06	0.098	0.067	0.108	0.193	0.433
CD at 5%	--	2.697	3.837	2.12	0.608	--	0.111	0.17	0.29	---	0.321	0.575	1.294

Table 2. Effect putrescine and Indole-3-butric acid on morpho-physiological parameters, yield and Harvest Index of groundnut

Treatments	RGR			NAR					
	20-35 DAS	35-50 DAS	50-65 DAS	20-35 DAS	35-50 DAS	50-65 DAS	Pod Yield (q)	B :C ratio	Harvest Index
T_1 (control)	0.0735	0.0400	0.0209	0.1048	0.0706	0.0403	16.99	2.69	20.51
T_2 (25 ppm putrescine)	0.0739	0.0407	0.0211	0.1062	0.0752	0.0426	19.06	2.46	21.42
T_3(50 ppm putrescine)	0.0753	0.0421	0.0220	0.1109	0.0812	0.0457	19.82	2.16	22.18
T_4 (75 ppm putrescine)	0.0755	0.0430	0.0222	0.1120	0.0849	0.0458	20.04	1.89	22.70
T_5 (100 ppm putrescine)	0.0757	0.0447	0.0225	0.1138	0.0858	0.0471	21.36	1.78	23.47
T_6 (25 ppm IBA)	0.0738	0.0401	0.0209	0.1054	0.0730	0.0404	18.91	2.78	20.59
T_7 (50 ppm IBA)	0.0743	0.0420	0.0218	0.1063	0.0797	0.0443	19.53	2.68	21.44
T_8 (75ppm IBA)	0.0756	0.0438	0.0223	0.1127	0.0850	0.0468	20.58	2.65	22.73
T_9 (100 ppm IBA)	0.0760	0.0452	0.0227	0.1141	0.0862	0.0476	22.55	2.73	24.29
SE (m±)	0.0007	0.0008	0.0004	0.0017	0.0005	0.0005	0.722	--	0.306
CD at 5%	0.0020	0.0023	0.0011	0.0050	0.0014	0.0014	2.162	--	0.916

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