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MORPHO-PHYSIOLOGICAL AND YIELD RESPONSES OF PIGEONPEA TO FOLIAR SPRAYS OF POLYAMINE (PUTRESCINE) AND NAA

Ganesh. N. Jadhav[1], Rajesh. D. Deotale[2], Reshma. D. Shinde[3], Swapnil. D. Meshram[4] and Kekita H. Chute[5]

ABSTRACT

An experiment was conducted during the *kharif* season of 2016-2017 at farm of Botany section, College of Agriculture, Nagpur, to study the effect of foliar sprays of putrescine and NAA on morpho-physiological parameters and yield of pigeonpea cv. PKV- Tara. The experiment was laid out in randomized block design with eighteen treatments and three replications. The different treatments tried were 25 and 50 ppm NAA and 25, 50, 75, 100 and 125 ppm putrescine alone or in combination. One control (water spray) treatment was also taken. Spraying of putrescine and NAA alone and in combination were applied at 45 and 65 DAS. Foliar sprays of 50 ppm NAA + 100 ppm putrescine followed by 50 ppm NAA + 75 ppm putrescine significantly enhanced plant height, leaf area, dry matter, RGR, NAR, yield ha^{-1}and harvest index when compared with control and rest of the treatments under study. Considering the Benefit:Cost ratio 50 ppm NAA was found more economical having B:C ratio of 2.67 as compared to 2.26 in control.

(Key words: Pigeonpea, putrescine, NAA, foliar application, morpho-physiological parameters, yield)

INTRODUCTION

Pulses have been indispensible constituent of Indian diet. It is an important grain legume of the semiarid tropics and forms a significant component of the diet of vegetarians. Pigeonpea (*Cajanus cajan* L. Millsp.) is a important legume and belongs to family *Leguminaceae* and genus *Cajanus. Cajanus* is derived from Malay word '*katschang'* or '*katjang'* meaning pod or bean. According to FAO pigeonpea is also known as Red gram, tur, arhar, dal (India).Its drought tolerance and the ability to use residual moisture during the dry season make it an importance crop.

It is often cross pollinated crop (20 to 70 %) with diploid chromosome number 2n=22. Pigeonpea is widely grown in India and India is the largest producer and consumer of pigeonpea in the world. Area under pigeonpea during 2015-16 in India is 3.9 million ha, production 3.31 million tonnes and productivity 914 kg ha^{-1}. Pigeonpea is grown throughout the tropical and subtropical countries of the world especially in South Asia, Eastern and Southern Africa, Latin America, Caribbean countries and Australia.

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). Putrescine treatments significantly increased fresh and dry weights of bean plants. Putrescine at 10^{-5} M increased grain and biological yield and grain index of wheat plant (Gupta *et al*., 2003).

NAA (Naphthalene Acetic Acid) is the synthetic auxin with the identical properties to that naturally occurring auxin. It prevents formation of abscission layer and there by flower drop. It was observed that the growth regulators are involved in the direct transport of assimilates from source to sink (Sharma *et al*., 1989).

Considering the above facts present investigation was undertaken to study the responses of putrescine and NAA on morphophysiological parameters and yield of pigeonpea.

MATERIALS AND METHODS

Considering the above fact present work was undertaken to study the response of putrescine and NAA on morpho-physiological parameters and yield of pigeonpea.Experiment was laid out in randomized block design with eighteen treatments and three replications. Plot size of individual treatment was gross 4.20 m x 4.40 m and net 3.0 m x 4.0 m. Seeds were sown at the rate of 20 kg ha^{-1} by dibbling method at spacing of 60 cm x 20 cm on 1[st] July 2016. Treatments comprised of control (T_1), 25 ppm NAA (T_2), 50 ppm NAA (T_3), 25ppm putrescine (T_4), 50 ppm putrescine (T_5), 75 ppm putrescine (T_6), 100 ppm putrescine (T_7), 125 ppm putrescine (T_8), 25 ppm NAA + 25 ppm putrescine (T_9),

1, 3, 4 and 5. P.G. Students, Botany Section, College of Agriculture, Nagpur (MS), India
2. Professor, Botany Section, College of Agriculture, Nagpur (MS), India

25 ppm NAA + 50 ppm putrescine (T_{10}), 25 ppm NAA + 75 ppm putrescine (T_{11}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 25 ppm NAA + 125 ppm putrescine (T_{13}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 75 ppm putrescine(T_{16}), 50 ppm NAA + 100 ppm putrescine (T_{17}) and 50 ppm NAA + 125 ppm putrescine (T_{18}). The foliar application of putrescine and NAA was given at two stages i.e. at 45 and 65 DAS on pigeonpea. Observations on plant height, number of branches, leaf area plant^{-1}, total dry weight of plant, NAR, RGR were recorded at 45, 65, 85 and 105 DAS and seed yield ha^{-1} was also recorded after harvesting. Percent increase and B:C ratio were also calculated. The crop was kept free from disease and pest during the growth period. Harvesting was undertaken after the crop attained maturity. Data were analysed by statistical method suggested by Panse and Sukhatme (1954).

RESULTS AND DISCUSSION

Plant height

The data recorded about the plant height was subjected to statistical analysis and the results were found statistically significant. Significantly maximum plant height was recorded in treatments 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatment 50 ppm NAA + 75 ppm putrescine (T_{16}). Next to this treatment, 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7) and 25 ppm NAA + 75 ppm putrescine (T_{11}) also exhibited significantly more plant height when compared with control and rest of the treatments under observations. It was also noticed that the treatments like 25 ppm NAA + 125 ppm putrescine (T_{13}), 25 ppm NAA + 50 ppm putrescine (T_{10}), 25 ppm NAA + 25 ppm putrescine (T_9), 25 ppm putrescine (T_4) and 50 ppm putrescine (T_5) also increased the plant height over control and remaining treatments. Rest of the treatments were found at par with control (T_1).

Putrescine increased the growth character viz., plant height. This increased growth is due to polyamine application implied that they could act as a growth promoters. It also act as a source of nitrogen (Mirza and Bagni, 1991). Increased growth and allied character viz., plant height might be due to increased chlorophyll content (Thavaprakash *et al*., 2006). Application of polyamines would increase Rubisco activity (Pyke and Leech, 1987) as elevation of sink ‘demand’ on developing plants or increase Rubisco enzyme concentration in source leaves which resulted in increased growth and growth allied characters. Putrescine increased the growth characters viz., plant height, 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). This might be the reason for increased plant height in the present investigation.

Similarly Naphthalene Acetic Acid is a plant growth regulator having high efficiency. It improves the cell splitting and expansion. So, it might be a reason for increase in plant height by foliar application of NAA in combination with putrescine in pigeonpea.

The above observations are similar with the findings of Amin *et al*. (2013). They revealed the response of chickpea (*Cicer arietinum* L.) to treatment with 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 the plant height over control.

Wagh (2015) also tried two foliar sprays of putrescine and IBA @ 0, 50, 75, 100, 125 and 150 ppm at 30 and 45 DAS on soybean. He observed that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased plant height.

Number of branches plant^{-1}

Branches of a plant provide more area for the leaves to develop and capture more sunlight for photosynthesis. These branches then bear more flowers and fruits. So, more number of branches is a desirable attribute for higher biomass production and yield.

The range of number of branches observed was 17.16 - 28.33. Treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) was found significantly superior in increasing number of branches followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}) and 50 ppm NAA + 25 ppm putrescine (T_{14}) when compared with control and other treatments. It was also noticed that the treatments like 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7), 25 ppm NAA + 75 ppm putrescine (T_{11}) and 25 ppm NAA + 125 ppm putrescine (T_{13}) also increased number of the branches over control and other treatments. Remaining treatments were found at par with control (T_1).

It is clear from above data that foliar application of growth promoters putrescine and NAA increased number of branches plant^{-1}. Similar results were obtained by many scientists. Singh *et al*. (2015) observed that foliar application of 50 ppm NAA significantly enhanced number of branches plant^{-1} over control in fenugreek.

Amin *et al*. (2013) tested the response of chickpea (*Cicer arientinum* L.) to treatment with two plant growth regulators putrescine and Indole-3-butyric acid (IBA) @ 25, 50 and 100 mg l^{-1} applied either alone or in combinations. Higher values of growth parameter number of branches was registered with 100 mg l^{-1} of putrescine and IBA over control.

Leaf area

Data regarding leaf area were recorded at four growth stages viz., 45, 65, 85 and 105 DAS. Significant variation with gradual increase (65, 85 and 105 DAS) was noticed regarding leaf area at all the stages of observations. Leaf area at 45 DAS was found non significant because foliar sprays of putrescine and NAA were given from this stage onwards (40-45 DAS).At 65 DAS leaf area plant^{-1} was significantly influenced by different treatments. The range of leaf area recorded was 20.21 - 26.92 dm^2. At this stage treatments 50 ppm NAA + 100 ppm putrescine (T_{17}), 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7) and 25 ppm NAA + 75 ppm putrescine (T_{11}) in a descending manner noted significantly more leaf area when compared with control and rest of the treatments.

At 85 DAS the treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) was found superior in respect of leaf area over all the treatments and control, but treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}) were found at par with this treatment. Remaining treatments were found at par with control (T_1).

At 105 DAS leaf area plant^{-1} was significantly influenced by different treatments. At this stage treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7), 25 ppm NAA + 75 ppm putrescine (T_{11}) and 25 ppm NAA + 125 ppm putrescine (T_{13}) exhibited maximum leaf area in a desending manner when compared with control and rest of the treatments. Remaining treatments were found at par with control (T_1) in leaf area plant^{-1}.

Putrescine increased the growth character viz., leaf area. This increased growth in pigeanpea 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 of auxin (Mulkey, 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). These might also be the reasons for increase in leaf area in the present investigation. Physiological role of putrescine and NAA was also documented by several scientists.

Wagh (2015) conducted a field experiment to evaluate the response of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125, 150 ppm on soybean. He reported that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased leaf area. Arsode *et al*. (2014) observed that foliar application of 50 ppm NAA + 300 ppm HA through cowdung wash at 30 and 45 DAS significantly enhanced leaf area in mustard.

Total dry weight

The dry matter accumulation of individual plant was studied at each sampling i.e. 45, 65, 85, and 105 DAS.Data regarding dry matter gave significant variation at 65, 85 and 105 DAS. At 45 DAS the dry matter accumulation by various treatments was found non significant. At all the stages of observations foliar application of 50 ppm NAA + 100 ppm putrescine (T_{17}) produced significantly more dry matter and stood first in rank.

At 65 DAS dry matter was increased significantly by the treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}). Similarly 25 ppm NAA + 100 ppm putrescine (T_{12}) and 50 ppm NAA (T_3) also recorded more dry matter when compared with control. Remaining treatments were found at par with control (T_1) in respect of dry matter production.

At 85 DAS the range of dry matter production was 236.16 – 260.99 g. The highest dry matter production was noticed by the application of 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7) and 25 ppm NAA + 75 ppm putrescine (T_{11}). Remaining treatments were found at par with control (T_1).

At 105 DAS, foliar application of 50 ppm NAA + 100 ppm putrescine (T_{17}) resulted in more dry matter followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}) and 50 ppm NAA + 25 ppm putrescine (T_{14}). It was also noticed that the treatment 25 ppm NAA + 100 ppm putrescine (T_{12}) also increased dry matter production. Rest of the treatments were found at par with control (T_1).

Dry matter accumulation is a function of leaf area and maximum leaf area was observed during 45-65 DAS and it is period of maximum photosynthesis and yielded maximum dry matter production. 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. Putrescine (polyamines) application implied that they could act as a growth promoter (Mirza and Bagni, 1991). Similarly hormones regulate physiological process and synthetic growth regulators may enhance growth and development of field crops there by increased total dry mass of a field crop (Das and Das, 1996). These might be the reasons for increase in dry weight of pigeonpea plants due to application of putrescine and NAA in the present investigation.

Similar, results also confirmed by Mathur and Vyas (2007). They conducted a field experiment 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 dry weight. Kapase *et al*. (2014) reported that foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA and 300 ppm HA through VCW significantly enhanced total dry matter production plant^{-1} in chickpea.

Growth analysis

Relative growth rate (RGR)

Relative growth rate (RGR) represents total dry weight gained over existing dry weight in unit time. This was originally termed an "efficiency index" because it expresses growth in terms of a rate of increase in size unit^{-1} of size. In this regard, data recorded at 45-65, 65-85and 85-105 DAS. Considering all the treatments under study, significantly maximum RGR was noted in 50 ppm NAA + 100 ppm putrescine (T_{17}) treatment i.e.0.07960 g g^{-1} day^{-1}, while it was lowest in control i.e. 0.05948 g g^{-1} day^{-1} at 45-65 DAS. Treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) gave more RGR followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}) and 25 ppm NAA + 100 ppm putrescine (T_{12}) respectively when compared with control and rest of the treatments under study. Rest of the treatments were found at par with control (T_1) in RGR.

During 2nd phase (65-85 DAS) significantly maximum RGR was recorded in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}). Treatments 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7), 25 ppm NAA + 75 ppm putrescine (T_{11}), 25 ppm NAA + 125 ppm putrescine (T_{13}) and 25 ppm NAA + 50 ppm putrescine (T_{10}) also enhanced RGR significantly when compared with control and other treatments. Remaining treatments were found at par with control (T_1) in RGR.

During 3rd phase (85-105 DAS) significantly maximum RGR was observed in treatments 50 ppm NAA + 100 ppm putrescine (T_{17}) and 50 ppm NAA + 75 ppm putrescine (T_{16}). Similarly treatments 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}) and 25 ppm NAA + 100 ppm putrescine (T_{12}) also increased RGR significantly when compared with control and other treatments. Rest of the treatments were remain at par with control (T_1) in RGR.

The decrease in RGR of plants during the growth season is due to increase in structural tissues in comparison to photosynthetic tissues (Motaghi and Nejad, 2014).Wagh (2015) conducted a field experiment to evaluate the response of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125, 150 ppm on soybean. He reported that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased RGR.Kapase *et al*. (2014) studied the effect of humic acid through vermicompost wash and NAA and reported that foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA and 300 ppm HA through VCW significantly enhanced RGR in chickpea.

Net assimilation rate (NAR)

NAR is closely connected with photosynthetic efficiency of leaves, but it is not a pure measure of photosynthesis. NAR depends upon the excess dry matter gained, over the loss in respiration. It is increase in plant dry weight unit^{-1} area of assimilatory tissue unit^{-1} time. Considering the treatments under study, during 1st phase (45-65 DAS) significantly maximum NAR was noted in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3) and 100 ppm putrescine (T_7) in descending manner when compared with control and rest of the treatments. It was also noticed that the treatments like 25 ppm NAA + 75 ppm putrescine (T_{11}) and 25 ppm NAA + 125 ppm putrescine (T_{13}) also increased NAR over control and remaining treatments. But rest of the treatments were found at par with control (T_1) in respect of NAR.

During 2nd phase (65-85 DAS) significantly maximum NAR was observed in treatments 50 ppm NAA + 100 ppm putrescine (T_{17}), 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7), 25 ppm NAA + 75 ppm putrescine (T_{11}) and 25 ppm NAA + 125 ppm putrescine (T_{13}) when compared with control and rest of the treatments under study. But remaining treatments were found at par with control (T_1) in respect of NAR.

During 3rd phase (85-105 DAS) significantly maximum NAR was noted in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) when compared with control and rest of the treatments. Similarly treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7), 25 ppm NAA + 75 ppm putrescine (T_{11}) and 25 ppm NAA + 125 ppm putrescine (T_{13}) also registered significantly maximum NAR over control and rest of the treatments. The treatments 25 ppm NAA + 50 ppm putrescine (T_{10}) and 25 ppm NAA + 25 ppm putrescine (T_9) also increased NAR over control and remaining treatments. Remaining treatments were found at par with control (T_1) in respect of NAR.

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). Decrease in NAR during reproductive phase might be due to decrease efficiency of leaves for photosynthesis as a response to photosynthetic apparatus to increase demand for assimilates by growing seed fraction and sink demand on photosynthetic rate of leaves.

Mathur and Vyas (2007) conducted a field experiment 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 net assimilation rate.Wagh (2015) conducted a field experiment to evaluate the response of two foliar sprays (30 and 45 DAS) of putrescine and IBA @ 0, 50, 75, 100, 125, 150 ppm on soybean. He reported that two foliar sprays of putrescine and IBA @ 100 ppm significantly increased NAR.Kapase *et al.* (2014) observed that foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA and 300 ppm HA through VCW significantly enhanced RGR and NAR in chickpea.

Yield parameters

Seeds 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, number of branches and test weight which are considered as yield contributing parameters. Seed yield plant^{-1}, plot^{-1} and 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 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). Kelaiya *et al.* (1991) found increase in the yield of pods with 40 ppm NAA spray in groundnut. Kalita *et al.* (1995) reported that 3% P_2O_5 + 100 ppm NAA increased dry matter accumulation and partitioning and nitrogen accumulation reflected in higher yield in green gram.

The maximum seed yield hectare^{-1} was recorded in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}). The range of increase in seed yield hectare^{-1} was 15.43 q in treatment T_1 (control) to 20.27 q in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}).

Significantly maximum seed yield ha^{-1} was recorded in treatments 50 ppm NAA + 100 ppm putrescine (T_{17}) followed by treatments 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}), 50 ppm NAA + 25 ppm putrescine (T_{14}), 25 ppm NAA + 100 ppm putrescine (T_{12}), 50 ppm NAA (T_3), 100 ppm putrescine (T_7) when compared with control and rest of the treatments. Treatments 25 ppm NAA + 75 ppm putrescine (T_{11}), 25 ppm NAA + 125 ppm putrescine (T_{13}) and 25 ppm NAA + 50 ppm putrescine (T_{10}) also significantly enhanced seed yield ha^{-1} as compared to control and rest of the treatments.Remaining treatments were found at par with control (T_1).

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).

The increase in the yield recorded in this investigation could be a reflection of the effect of growth regulators putrescine and NAA on growth and development. It might also be due to marked increase in plant height, number of branches, leaf area and dry weight which gave a chance to the plant to carry more seeds 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. The above finding was in corroboration with the findings of Thavaprakash (2006) in green gram. They performed an experiment to study the effect of plant growth promoters putrescine and spermidine on assimilate partitioning and seed yield of green gram. Results revealed that 20 ppm of both putrescine and spermidine were found effective in increasing 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. The promotive effects of putrescine and NAA on the harvestable yields of pigeonpea indicated that the strengths (defined as sink size / sink activity) of reproductive parts are greatly increased, when compared with 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 seed yield, straw and biological yield feed^{-1} of chickpea (*Cicer arietinum*). Kapase *et al.* (2014) tried foliar application of humic acid through vermicompost wash and NAA on chickpea and reported that foliar spray of 50 ppm NAA + 400 ppm HA through VCW followed by 50 ppm NAA and 300 ppm HA through VCW significantly increased seed yield ha^{1}.

Harvest index (HI)

Significantly maximum harvest index was recorded in treatment 50 ppm NAA + 100 ppm putrescine (T_{17}) and minimum in control. The range of increased harvest index was 27.30 in control and 35.82 in above treatment.

Treatments 50 ppm NAA + 100 ppm putrescine (T_{17}), 50 ppm NAA + 75 ppm putrescine (T_{16}), 50 ppm NAA + 50 ppm putrescine (T_{15}) and 50 ppm NAA + 25 ppm

Table 1. Effect of putrescine and NAA on plant height, number of branches, leaf area and total dry weight

Treatments	Plant height (cm)	Number of branches plant^{-1}	Leaf area plant^{-1} (dm^2)				Total dry weight plant^{-1} (g)			
			45 DAS	65 DAS	85 DAS	105 DAS	45 DAS	65 DAS	85 DAS	105 DAS
T_1 (Control)	245.16	17.16	6.15	20.21	38.21	53.21	6.41	32.08	236.16	328.47
T_2 (25 ppm NAA)	251.78	18.97	6.17	21.22	39.30	55.43	7.00	33.68	242.97	337.42
T_3 (50 ppm NAA)	260.36	23.51	6.20	24.87	43.93	67.63	8.27	40.97	251.76	346.53
T_4 (25 ppm Putrescine)	256.60	20.78	6.23	22.90	41.32	59.46	7.47	35.29	246.22	341.10
T_5 (50 ppm Putrescine)	255.39	20.29	6.35	22.42	41.28	57.22	7.28	34.83	246.04	340.13
T_6 (75 ppm Putrescine)	253.48	19.47	6.47	22.33	40.19	56.92	7.16	34.62	245.36	339.29
T_7 (100 ppm Putrescine)	259.94	23.11	6.59	24.59	42.38	66.45	8.18	39.36	250.40	346.12
T_8 (125 ppm Putrescine)	246.60	18.20	6.10	21.03	39.10	54.74	6.73	32.18	240.48	335.68
T_9 (25 ppm NAA + 25 ppm Putrescine)	256.97	21.14	6.13	23.68	41.67	62.64	7.51	36.37	246.53	342.57
T_{10} (25 ppm NAA + 50 ppm Putrescine)	257.73	21.62	6.22	23.74	42.32	63.28	7.58	36.72	247.35	343.26
T_{11} (25 ppm NAA + 75 ppm Putrescine)	259.35	22.93	6.29	24.17	42.90	65.92	7.92	38.22	249.33	345.10
T_{12} (25 ppm NAA + 100 ppm Putrescine)	261.11	24.12	6.40	24.94	44.39	68.85	8.39	42.71	252.29	350.17
T_{13} (25 ppm NAA + 125 ppm Putrescine)	258.50	22.54	6.32	23.82	42.76	65.22	7.70	37.03	248.17	344.59
T_{14} (50 ppm NAA + 25 ppm Putrescine)	262.43	25.63	6.47	25.00	44.49	69.13	8.47	43.44	253.24	354.75
T_{15} (50 ppm NAA + 50 ppm Putrescine)	263.00	26.75	7.19	25.10	46.20	72.37	8.65	46.64	255.15	359.29
T_{16} (50 ppm NAA + 75 ppm Putrescine)	265.60	28.07	7.50	26.52	46.85	73.30	8.70	48.18	257.76	365.85
T_{17} (50 ppm NAA + 100 ppm Putrescine)	266.39	28.33	7.85	26.92	47.82	74.84	9.00	49.89	260.99	372.17
T_{18} (50 ppm NAA + 125 ppm Putrescine)	252.12	19.10	6.15	21.41	39.62	55.95	7.10	34.49	244.91	338.36
SE (m) ±	2.619	1.377	0.352	1.05	1.861	3.893	0.495	2.382	4.093	7.032
CD at 5%	7.806	4.104	-	3.13	5.548	11.602	-	7.101	12.198	20.958

Table 2. Effect of putrescine and NAA on RGR, NAR, Seed yield ha^{-1}, harvest index and B:C ratio

Treatments	RGR (g g^{-1} day^{-1})			NAR (g dm^{-2} day^{-1})			Seed yield ha^{-1}	Harvest index	B:C ratio
	45-65 DAS	65-85 DAS	85-105 DAS	45-65 DAS	65-85 DAS	85-105 DAS			
T_1 (Control)	0.05948	0.07130	0.01649	0.10206	0.29110	0.09246	15.43	27.3	2.26
T_2 (25 ppm NAA)	0.06167	0.07213	0.01712	0.10460	0.29330	0.10180	16.04	28.02	2.34
T_3 (50 ppm NAA)	0.06986	0.07905	0.01875	0.12610	0.32880	0.13359	18.33	30.93	2.67
T_4 (25 ppm Putrescine)	0.06403	0.07482	0.01757	0.11076	0.31270	0.11398	17.63	28.84	2.32
T_5 (50 ppm Putrescine)	0.06314	0.07373	0.01742	0.10905	0.31240	0.11295	17.05	28.68	2.03
T_6 (75 ppm Putrescine)	0.06250	0.07325	0.01739	0.10890	0.31090	0.10992	16.75	28.42	1.82
T_7 (100 ppm Putrescine)	0.06846	0.07876	0.01844	0.12245	0.32840	0.13127	18.23	30.45	1.83
T_8 (125 ppm Putrescine)	0.06147	0.07182	0.01697	0.10228	0.29150	0.10152	15.83	27.95	1.47
T_9 (25 ppm NAA + 25 ppm Putrescine)	0.06407	0.07524	0.01769	0.11130	0.32080	0.12342	17.73	29.21	2.32
T_{10} (25 ppm NAA + 50 ppm Putrescine)	0.06580	0.07638	0.01778	0.11295	0.32290	0.12512	17.76	29.76	2.11
T_{11} (25 ppm NAA + 75 ppm Putrescine)	0.06706	0.07811	0.01841	0.11450	0.32790	0.12996	17.94	30.19	1.95
T_{12} (25 ppm NAA + 100 ppm Putrescine)	0.06993	0.07956	0.01967	0.12771	0.33110	0.13516	18.46	32.22	1.84
T_{13} (25 ppm NAA + 125 ppm Putrescine)	0.06689	0.07746	0.01792	0.11310	0.3270	0.12855	17.83	29.9	1.65
T_{14} (50 ppm NAA + 25 ppm Putrescine)	0.07233	0.08121	0.02085	0.12983	0.33680	0.13590	18.87	33.45	2.46
T_{15} (50 ppm NAA + 50 ppm Putrescine)	0.07589	0.08235	0.02111	0.13100	0.34340	0.13856	19.52	34.28	2.31
T_{16} (50 ppm NAA + 75 ppm Putrescine)	0.07657	0.08273	0.02275	0.13218	0.34620	0.14245	20.10	35.39	2.18
T_{17} (50 ppm NAA + 100 ppm Putrescine)	0.07960	0.08385	0.02474	0.13252	0.35453	0.14935	20.27	35.82	2.00
T_{18} (50 ppm NAA + 125 ppm Putrescine)	0.06220	0.07441	0.01728	0.10460	0.30140	0.109051	16.40	28.1	1.51
SE (m) ±	0.00344	0.00128	0.000721	0.00342	0.01051	0.00722	0.755	1.131	-
CD at 5%	0.01026	0.00382	0.00215	0.01022	0.03134	0.02152	2.252	3.373	-

putrescine (T_{14}) increased harvest index significantly over control and rest of the treatments. Similarly treatment 25 ppm NAA + 100 ppm putrescine (T_{12}) also increased the harvest index significantly over control and remaining treatments. Remaining treatments were found at par with control (T_1) in respect of harvest index.

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 straw yield and harvest index when applied at 30 or 60 DAS over control.

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

The analysis of B:C ratio due to expenditure incurred under different treatments of putrescine and NAA revealed that highest Benefit:Cost ratio was calculated in treatment (T_3) 50 ppm NAA (2.67) followed by treatments (T_{13}), 50 ppm NAA + 25 ppm putrescine (2.46) and (T_2) 25 ppm NAA (2.34) as compared to 2.26 for control (T_1).

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