J. Soils and Crops 27 (1) 124-131, June 2017 ISSN 0971-2836

EFFECT OF FOLIAR SPRAY OF PUTRESCINE AND NAA ON MORPHO-PHYSIOLOGICAL PARAMETERS AND YIELD OF CHICKPEA

Vikas R. Jaybhaye[1], R. D. Deotale[2], M. M. Neware[3], B. B. Pandey[4], V. J. Surywanshi[5] and Y. A. Chinmalwar[6]

ABSTRACT

Field study was conducted at farm of Botany, College of agriculture, Nagpur, during *rabi* 2015-2016 with two plant growth regulators viz., putrescine (25, 50, 75, 100, 125, 150 ppm) and NAA (25, 50 ppm) applied either alone or in combination to determine their effects on morpho-physiological parameters and yield of chickpea (Jaki-9218). The growth regulators were applied as foliar spray at 30-35 DAS. Results showed that foliar spray of 50 ppm NAA with 100 ppm putrescine significantly increased plant height, leaf area, dry weight, number of secondary branches, length of secondary branches, RGR and NAR respectively over water spray which resulted due to better, balanced plant growth and greater partitioning of assimilates towards yield formation as evidenced by higher seed yield ha^{-1}, per cent increase in yield and harvest index. But, considering the B: C ratio foliar application of 50 ppm NAA was found most effective having B: C ratio of 5.9 as compared to 5.1 in control. Hence, this treatment can be consider as a most effective treatment.

(Key words: Chickpea, putrescine, NAA, growth, morpho-physiological, parameters yield)

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third most important cool season food legume in the world after dry beans and peas (Anonymous, 2006). Chickpea is a diploid with 2n = 2x = 16 (Arumuganathan and Earle, 1991) having a genome size of approximately 931 Mbp. Chickpea is a self-pollinated crop. Cross-pollination is rare; only 0-1 % is reported (Singh, 1987). The genus *Cicer* belongs to the family Leguminosae, subfamily Papilionoideae, tribe *Cicereae* and comprises 43 species, nine of which being annual including chickpea (*Cicer arietinum* L.), while the rest are perennial (Vander Maesen, 1987). Chickpea is currently cultivated in over 40 countries worldwide and grown on 11 million hectares producing around 9 million ton in 2005 growing season (Anonymous, 2006). Two main types of chickpea cultivars are grown globally–

kabuli and *desi,* representing two diverse gene pools. The *kabuli* types are generally grown in the Mediterranean region including Southern Europe, Western Asia and Northern Africa and the *desi* types are grown mainly in Ethiopia and Indian subcontinent (Pundir *et al.,* 1985).

Plant growth regulators (PGRs) are representing one of the controlling factors that regulate growth, biosynthesis of chemical constituents, yield and may be improve adaptation of plants to environment. Polyamines (PAs) are polycationic compounds of low molecular weight that are present in all living organisms (Cohen, 1998). Some studies have shown the positive effects of PAs on cell division and its rate (Cvikrova *et al*., 1999), morphogenesis, floral initiation and development (Khan *et al*., 2012). PAs effectively retard senescence by retarding the loss of chlorophyll (Couee *et al*., 2004). Putrescine application (up to 5 mM) significantly increased the content of photosynthetic pigments of wheat (*Triticum aestivum*) plants (El-Bassiouny *et al*., 2008). PAs have been shown to be an integral part's response to stress (Alcazar *et al*., 2006). Exogenous putrescine and spermidine markedly modified the stress-induced effects in plants (Amooaghaie, 2011). Moreover, 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 occuring auxin. It prevents formation of abscission layer and thereby 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).

Therefore, effect of spraying chickpea plants with different concentrations of putrescine and NAA, individually or in combination on morpho-physiological criteria and yield parameters were assessed in this work.

MATERIALS AND METHODS

The field experiment was carried out during *rabi* season in 2015-16 at experimental farm of Agricultural Botany Section, College of Agriculture, Nagpur to study the effect of foliar sprays of different concentrations of putrescine and NAA, individually or in combination on morpho- physiological parameters and yield of chickpea.

1, 3, 4, 5 and 6. P.G. Students, Botany Section, College of Agriculture, Nagpur (M.S.)
2. Professor, Botany Section, College of Agriculture, Nagpur (M.S.)

The experimental design was RBD with 3 replications (Table 1). The foliar sprays of putrescine and NAA, individually or in combination were given as per treatments (Table 1) at 30-35 DAS. Jaki-9218 cultivar of chickpea was used in the experiment and sown on 10th Nov.2015 in *rabi* season. The plant growth characters were measured at 25, 45, 65 and 85 days after sowing i.e., plant height, leaf area and dry weight. Data regarding number of branches recorded at the time of harvesting. RGR and NAR also calculated at 25-45, 45-65 and 65-85 DAS stages. At harvest time, five selected plants were taken out from the five rows of each plot to determine the mean value of seed yield ha^{-1}, per cent increase in yield and B: C ratio. Harvest index was also calculated.

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)

The data on plant height influenced by plant growth promoters putrescine and NAA at four observational stages viz., 25, 45, 65 and 85 DAS of chickpea and are presented in table 1. At 45 DAS there was slow increase in plant height because foliar sprays of putrescine and NAA were given at 30-35 DAS. Thereafter, a tremendous increase in plant height was noticed till 85 DAS. Among all the treatments at 45 DAS significantly maximum plant height was recorded in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine) and T_9 (50 ppm NAA) when compared with treatment T_1 (control) and remaining treatments under study. Also, treatments T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine) and T_{11} (25 ppm NAA + 50 ppm putrescine) were found significantly superior over treatment T_1 (control). Whereas remaining treatments were found at par with control. At 65 DAS it was noticed that significantly highest plant height was recorded in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA) and T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and rest of the treatments. Whereas, remaining treatments were found at par with control. At 85 DAS significantly maximum plant height was registered in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA) and T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine) and T_{14} (25 ppm NAA + 125 ppm putrescine) in a descending manner when compared with treatment T_1 (control) and remaining treatments under study. Whereas remaining treatments were found at par with control. 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 ., 1979). This might be the reasons for increase in 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 chickpea. On the other hand, this implies that linearity of the plant height is directly related to the endogenous level of auxin concentration. These observations were similar to the findings of Wagh (2015). He tried two foliar sprays of putrescine and IBA @ 0, 50, 75, 100, 125, 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. Similarly, Arsode (2013) reported that foliar application of 50 ppm NAA + 300 ppm HA through cowdung wash at 30 and 45 DAS significantly enhanced plant height in mustard.

Leaf area $plant^{-1}$ (dm^2)

Leaf area gives a fairly good idea of the photosynthetic capacity of the plant, because it plays an important role in absorption of light, radiation and using it in photosynthesis process. Leaf area depends upon the number and size of leaves. Leaf size is influenced by light, moisture and nutrients. It also follows the trend of plant height. Hence, yield is dependent on leaf area of crop. Data regarding leaf area were recorded at four growth stages i.e. 25, 45, 65 and 85 DAS. The data are given in table 1. At 45 and 85 DAS significantly maximum leaf area were noticed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine) and T_{11} (25 ppm NAA + 50 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study. Also, treatment T_{10} (25 ppm NAA + 25 ppm putrescine) was found significantly superior over treatment T_1 (control). But remaining treatments were found at par with control. At 65 DAS significantly maximum leaf area was found in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine),

T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine) and T_{12} (25 ppm NAA + 75 ppm putrescine) when compared with treatment T_1 (control) and remaining treatments under study. Similarly treatments T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine) and T_{14} (25 ppm NAA + 125 ppm putrescine) also increased leaf area significantly over control and rest of the treatments under study. When nutrients and hormones applied through foliar spray, might have accelerated the metabolic and physiological activities of plant and put up more growth by assimilating more amount of major nutrients and ultimately increased leaf area. Putrescine increased the growth character viz., leaf area. This increased growth in chickpea 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). It can also induce the synthesis of RNase enzyme, which enhances the 'N' use efficiency (Bagni , 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. 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 leaf area when applied at 30 or 60 DAS over control. Kapase. (2013) studied the effect 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 enhanced leaf area.

Dry weight of plant^{-1} (g)

Total dry matter production, its distribution and partitioning is the integral part of the growth and development over the entire growth period and is directly related to the seed yield. Data pertaining to the dry matter production plant^{-1} recorded at different stages (i.e. 25, 45, 65 and 85 DAS) are presented in table 1. There was an increase in total dry weight with an advancement of crop growth and maximum total dry matter production was observed at 85 DAS. It was observed that treatments differed significantly at all stages except at 25 DAS, because foliar sprays of growth promoters Putrescine and NAA of different concentrations were given from this stage onwards (30-35 DAS). At 45 DAS significantly maximum dry matter production was noticed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA) and T_5 (100 ppm putrescine) when compared with treatment T_1 (control) and rest of the treatments under observations. Similarly, treatments T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15} (25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine) and T_{21} (50 ppm NAA + 150 ppm putrescine) also gave significantly more dry matter in a descending manner when compared with treatment T_1 (control). But remaining treatments were found at par with control. At 65 and 85 DAS significantly highest dry matter was recorded in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatment T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine) and T_{16} (50 ppm NAA + 25 ppm putrescine) when compared with control (T_1) and rest of the treatments under observations. Next to these, treatments T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15} (25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine), T_{21} (50 ppm NAA + 150 ppm putrescine) and T_8 (25 ppm NAA) also gave significantly more dry matter when compared with treatment T_1 (control). While remaining treatments were found at par with control. From the data it is cleared that dry matter increased gradually from 1st - 2ndstage of observation. Dry matter accumulation is a function of leaf area and maximum leaf area was observed during 45-65 DAS and it is the 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 processes 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 chickpea 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. Deotale *et al*. (2010) studied the effect of foliar sprays of 2-6% cow urine and 50 ppm NAA on morpho-physiological parameters of black gram. Results exhibited that foliar application of 6% cow urine +50 ppm NAA significantly increased total dry matter of black gram.

Data regarding number of secondary branches and length of secondary branches plant^{-1} were recorded at harvest and illustrated in table 1. It is revealed from the data that highest number of secondary branches and length of secondary branches plant^{-1} were observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine) and T_{13} (25 ppm NAA + 100 ppm putrescine) when compared with treatment T_1(control) and rest of the treatments under study. But remaining treatments were found at par with control. Branches are the sites of the leaves, flower and pod formation. Hence, they are closely associated with the photosynthetic activity and yield of plant. So, number of branches is a desirable attribute for higher biomass production and yield. It was clear from above data that foliar application of growth promoters Putrescine and NAA increased number of secondary branches plant^{-1}. Similar results were obtained by many scientists. Basole *et al.* (2013) tested foliar application of 50 ppm NAA and nutrients ($FeSo_4$, KNo_3, $ZnSO_4$, $MgSO_4$ 0.55%) on soybean and concluded that NAA and nutrients with $^1/_2$ RDF increased number of branches plant^{-1} over control.

Growth analysis

The productivity of crop may be related with the parameters such as RGR, NAR and partitioning of total photosynthates into economic and non-economic sink.

Relative growth rate

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.

The data regarding RGR are given in table 2. At first stage i.e. 25-45 DAS significantly maximum RGR was observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine). Treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine) and T_{16} (50 ppm NAA + 25 ppm putrescine) were found superior when compared with treatment T_1 (control) and remaining treatments under study. Treatments T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15}(25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine), T_{21} (50 ppm NAA + 150 ppm putrescine), T_8 (25 ppm NAA), T_4 (75 ppm putrescine), T_3 (50 ppm putrescine) and T_6 (125 ppm putrescine) also registered significantly more RGR when compared with T_1 (control). Treatments T_7 (150 ppm putrescine) and T_2 (25 ppm putrescine) were found at par with T_1 (control). At second stage i.e. 45-65 DAS significantly maximum RGR was observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine). Treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine) and T_{13} (25 ppm NAA + 100 ppm putrescine) when compared with T_1 (control). Whereas remaining treatments were found at par with control in RGR. At third stage i.e. 65-85 DAS significantly maximum RGR was observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine). Treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine) and T_{15} (25 ppm NAA + 150 ppm putrescine) were also gave significantly more RGR over control (T_1). While remaining treatments were found at par with control. 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). The positive effects of these substances for chickpea plant are in agreement with Wagh (2015). He concluded that the effect 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 in soybean. Accordingly, Kapase (2013) pointed that 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

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. The analysed data of NAR are presented in table 2. At 25-45 DAS significantly maximum NAR was calculated in treatment T_{19} (50 ppm NAA + 100 ppm putrescine). Treatments T_{18} (50 ppm NAA + 75 ppm putrescine) and T_{17} (50 ppm NAA + 50 ppm putrescine) were found superior when compared with treatment T_1 (control). Similarly, treatments T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15} (25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine), T_{21} (50 ppm NAA + 150 ppm putrescine), T_8 (25 ppm NAA), T_4 (75 ppm putrescine), T_3 (50 ppm putrescine) and T_6 (125 ppm putrescine) were registered more NAR as compared to control (T_1). While remaining treatments were found at par with control in NAR. At 45-65 DAS significantly maximum NAR was observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine),

T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine), T_{12} (25 ppm NAA + 75 ppm putrescine) and T_{11} (25 ppm NAA + 50 ppm putrescine) over control (T_1) in a descending manner. Treatments T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15} (25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine) and T_{21} (50 ppm NAA + 150 ppm putrescine) were also gave maximum NAR when compared with treatment T_1 (control). But remaining treatments were found at par with T_1 (control) in NAR. At 65-85 DAS significantly maximum NAR was observed in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine) and T_{13} (25 ppm NAA + 100 ppm putrescine) in a descending manner over control (T_1). Treatments T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine), T_{10} (25 ppm NAA + 25 ppm putrescine), T_{14} (25 ppm NAA + 125 ppm putrescine), T_{15} (25 ppm NAA + 150 ppm putrescine), T_{20} (50 ppm NAA + 125 ppm putrescine), T_{21} (50 ppm NAA + 150 ppm putrescine), T_8 (25 ppm NAA) and T_4 (75 ppm putrescine) were also gave maximum NAR when compared with treatment T_1 (control). Whereas remaining treatments were found at par with control in NAR. 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. El-hendi *et al*. (2011) also opined that as the plant gets older NAR decreases due to leaves aging and their shadows on each other and decrease of active photosynthetic area. Similar observations also recorded by Wagh (2015). He studied the effect 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 in soybean.

Yield parameters

Yield is complex character determined by several traits internal plant processes and environmental factors. In present study data on effect of putrescine and NAA on seed yield ha^{-1}, per cent increase in yield, B: C ratio and Harvest Index are presented in table 2.

Seed yield ha^{-1}(q)

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, number of secondary branches, length of branches, number of pods $plant^{-1}$ and 100 seed weight which are considered as yield contributing parameters. Significantly maximum seed yield ha^{-1} was recorded in treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine) , T_{12} (25 ppm NAA + 75 ppm putrescine), T_{11} (25 ppm NAA + 50 ppm putrescine) and T_{10} (25 ppm NAA + 25 ppm putrescine) when compared with control and rest of the treatments under observations. Whereas remaining treatments were found at par with control. 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, 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 *et al.* (2006) in green gram. The promotive effects of Putrescine and NAA on the harvestable yields of chickpea indicated that the strengths (defined as sink size / sink activity) of reproductive parts are greatly increased, when compared with control. Amin *et al*. (2013) observed the same findings with the application 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 arietinum*). Similarly Kapase (2013) studied the effect 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

Harvest index represents the ultimate partitioning of dry matter between seed (economic yield), vegetative parts (biological yield). Harvest index was significantly influenced by treatment T_{19} (50 ppm NAA + 100 ppm putrescine) followed by treatments T_{18} (50 ppm NAA + 75 ppm putrescine), T_{17} (50 ppm NAA + 50 ppm putrescine), T_{16} (50 ppm NAA + 25 ppm putrescine), T_9 (50 ppm NAA), T_5 (100 ppm putrescine), T_{13} (25 ppm NAA + 100 ppm putrescine) , T_{12} (25 ppm NAA + 75 ppm putrescine) and T_{11} (25 ppm NAA + 50 ppm putrescine) increased harvest index when compared with control and rest of the treatments. While remaining treatments were found at par with control. Similar results were recorded by 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

Table 1. Effect of putrescine and NAA on plant height (cm), leaf area (dm^2), dry weight (g) and number of secondary branches in chickpea

Treatments	Plant height (cm)			Leaf area (dm^2)			Dry weight (g)			No. of secondary branches	Length of secondary branches (cm)
	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS		
T_1 (control)	18.07	30.03	42.61	1.14	1.31	1.51	1.18	2.05	2.66	26.50	18.47
T_2 (25 ppm putrescine)	18.15	30.11	43.60	1.15	1.35	1.52	1.22	2.18	2.83	27.00	18.68
T_3(50 ppm putrescine)	19.83	31.79	45.07	1.27	1.48	1.61	1.40	2.49	3.29	28.00	20.26
T_4 (75 ppm putrescine)	19.92	31.87	45.67	1.29	1.50	1.63	1.48	2.64	3.50	28.50	20.60
T_5 (100 ppm putrescine)	22.70	34.93	50.87	1.60	1.91	2.14	1.97	3.83	5.44	32.75	25.10
T_6 (125 ppm putrescine)	19.77	31.73	44.53	1.24	1.44	1.56	1.35	2.40	3.16	27.75	19.57
T_7 (150 ppm putrescine)	19.41	31.38	43.71	1.22	1.41	1.55	1.28	2.29	2.99	27.25	19.12
T_8 (25 ppm NAA)	20.12	32.07	46.90	1.30	1.52	1.73	1.53	2.76	3.68	28.75	21.10
T_9 (50 ppm NAA)	23.08	35.05	51.01	1.63	1.96	2.27	2.04	3.95	5.62	33.00	25.29
T_{10} (25 ppm NAA + 25 ppm putrescine)	21.71	33.66	49.13	1.44	1.72	1.94	1.76	3.35	4.71	30.75	23.67
T_{11} (25 ppm NAA + 50 ppm putrescine)	21.93	33.91	49.82	1.48	1.75	1.97	1.78	3.44	4.85	31.00	24.26
T_{12} (25 ppm NAA + 75 ppm putrescine)	22.51	34.45	50.04	1.53	1.82	2.04	1.84	3.55	5.03	31.50	24.39
T_{13} (25 ppm NAA + 100 ppm putrescine)	22.70	34.68	50.39	1.58	1.87	2.11	1.91	3.69	5.22	32.00	24.59
T_{14} (25 ppm NAA + 125 ppm putrescine)	21.22	33.17	48.75	1.40	1.66	1.89	1.72	3.26	4.53	30.25	23.16
T_{15} (25 ppm NAA + 150 ppm putrescine)	20.95	32.90	48.33	1.37	1.60	1.83	1.69	3.15	4.36	29.75	22.49
T_{16} (50 ppm NAA + 25 ppm putrescine)	24.13	36.09	51.63	1.69	2.02	2.26	2.10	4.16	5.93	33.25	25.52
T_{17} (50 ppm NAA + 50 ppm putrescine)	24.28	36.21	51.39	1.71	2.04	2.29	2.18	4.32	6.17	33.50	26.46
T_{18} (50 ppm NAA + 75 ppm putrescine)	26.89	37.91	52.34	1.73	2.07	2.33	2.24	4.42	6.33	34.00	27.45
T_{19} (50 ppm NAA + 100 ppm putrescine)	27.02	38.04	52.46	1.77	2.14	2.39	2.34	4.64	6.65	34.50	28.26
T_{20} (50 ppm NAA + 125 ppm putrescine)	20.63	32.60	47.95	1.34	1.57	1.79	1.64	3.04	4.17	29.25	22.17
T_{21} (50 ppm NAA + 150 ppm putrescine)	20.32	32.28	47.78	1.33	1.55	1.75	1.60	2.92	3.89	29.00	21.45
SE (m)±	1.31	1.66	2.144	0.102	0.119	0.136	0.13	0.230	0.310	1.824	1.412
CD at 5%	3.75	4.75	6.127	0.290	0.341	0.388	0.382	0.670	0.891	5.213	4.036

Table 2. Effect of putrescine and NAA on RGR, NAR, seed yield ha^{-1}, per cent increase in yield, B: C ratio and Harvest Index in chickpea

Treatments	RGR g g^{-1} day^{-1}			NAR g dm^{-2} day^{-1}			Seed yield ha^{-1}	Per cent increase in yield	B: C ratio	Harvest Index (%)
	25-45 DAS	45-65 DAS	65-85 DAS	25-45 DAS	45-65 DAS	65-85 DAS				
T_1 (control)	0.01031	0.02847	0.01302	0.01066	0.03719	0.02152	18.13	-	5.1	32.21
T_2 (25 ppm putrescine)	0.01146	0.02879	0.01310	0.01200	0.03794	0.02229	18.81	3.75	4.5	32.74
T_3 (50 ppm putrescine)	0.01747	0.02914	0.01393	0.01888	0.04007	0.02590	19.93	9.92	4.1	33.87
T_4 (75 ppm putrescine)	0.01876	0.02927	0.01409	0.02069	0.04201	0.02804	20.07	10.70	3.7	34.25
T_5 (100 ppm putrescine)	0.02691	0.03324	0.01754	0.03112	0.05314	0.03978	22.73	25.37	3.7	37.81
T_6 (125 ppm putrescine)	0.01564	0.02913	0.01375	0.01680	0.03933	0.02517	19.62	8.21	2.9	33.52
T_7 (150 ppm putrescine)	0.01386	0.02908	0.01316	0.01482	0.03831	0.02356	19.29	6.39	2.6	33.27
T_8 (25 ppm NAA)	0.01882	0.02985	0.01424	0.02140	0.04370	0.02865	20.43	12.68	5.5	34.96
T_9 (50 ppm NAA)	0.02841	0.03328	0.01763	0.03214	0.05352	0.04030	22.86	26.08	5.9	38.11
T_{10} (25 ppm NAA + 25 ppm putrescine)	0.02259	0.03203	0.01718	0.02571	0.04999	0.03749	21.69	19.63	5.0	36.53
T_{11} (25 ppm NAA + 50 ppm putrescine)	0.02271	0.03279	0.01732	0.02574	0.05111	0.03801	21.97	21.18	4.4	36.96
T_{12} (25 ppm NAA + 75 ppm putrescine)	0.02437	0.03285	0.01742	0.02736	0.05120	0.03830	22.25	22.72	4.0	37.19
T_{13} (25 ppm NAA + 100 ppm putrescine)	0.02554	0.03305	0.01747	0.02891	0.05154	0.03861	22.47	23.93	3.6	37.49
T_{14} (25 ppm NAA + 125 ppm putrescine)	0.02235	0.03148	0.01660	0.02538	0.04979	0.03600	21.28	17.37	3.1	36.20
T_{15} (25 ppm NAA + 150 ppm putrescine)	0.02087	0.03128	0.01625	0.02407	0.04942	0.03523	21.09	16.32	2.8	35.93
T_{16} (50 ppm NAA + 25 ppm putrescine)	0.03054	0.03405	0.01776	0.03464	0.05540	0.04130	23.11	27.46	5.1	38.47
T_{17} (50 ppm NAA + 50 ppm putrescine)	0.03197	0.03419	0.01782	0.03693	0.05707	0.04235	23.44	29.28	4.2	38.97
T_{18} (50 ppm NAA + 75 ppm putrescine)	0.03267	0.03420	0.01787	0.03797	0.05764	0.04314	23.91	31.88	4.1	39.28
T_{19} (50 ppm NAA + 100 ppm putrescine)	0.03339	0.03422	0.01799	0.04159	0.05884	0.04432	24.18	33.37	3.8	39.62
T_{20} (50 ppm NAA + 125 ppm putrescine)	0.02042	0.03085	0.01502	0.02367	0.04796	0.03356	20.96	15.60	3.0	35.56
T_{21} (50 ppm NAA + 150 ppm putrescine)	0.01933	0.03039	0.01434	0.02181	0.04620	0.02922	20.83	14.89	2.7	35.20
SE (m)±	0.0014	0.0015	0.0010	0.0016	0.0029	0.0021	1.236	-	-	1.634
CD at 5%	0.0040	0.0044	0.0028	0.0045	0.0084	0.0060	3.533	-	-	4.670

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. From overall results, it can be stated that foliar application of growth regulators such as putrescine and NAA with different concentrations improved the morpho-physiological and yield parameters might have helped in attaining better seed yield in the present investigation.

The highest per cent increase in yield over control was observed in foliar application of 50 ppm NAA + 100 ppm putrescine (T_{19}) i.e. 33.37 % over control (T_1). But, considering the B: C ratio foliar application of 50 ppm NAA was found most effective treatment having B: C ratio of 5.9 as compared to 5.1 in control. Finally on the basis of B: C ratio it is inferred that, spraying plants at vegetative stage (30-35 DAS) with 50 ppm NAA 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 chickpea.

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Rec. on 02.05.2016 & Acc. on 04.06.2016