

**Morpho-physiological traits and productivity  
in garden pea (*Pisum sativum* L.) as  
influenced by various methods of Potassium  
humate - 4.5 application**

**THESIS**

*Submitted to the*

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfilment of the requirements  
For the Degree of

**MASTER OF SCIENCE**

*In*

**AGRICULTURE  
(PLANT PHYSIOLOGY)**

*By*

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**2015**

## CERTIFICATE – I

*This is to certify that the thesis entitled “**Morpho-physiological traits and productivity in Garden pea (Pisum sativum L.) as influenced by various methods of Potassium humate - 4.5 application**” submitted in partial fulfillment of the requirement for the degree of **Master of Science in Agriculture** in the **Department of Plant Physiology**, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Dhanraj Patel** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.*

*All the assistance and help received during the course of the investigation has been acknowledged by him.*

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I **Dhanraj Patel** S/o Shri Dharam Singh Patel Certify the work embodied in thesis entitled “**Morpho-physiological traits and productivity in Garden pea (*Pisum sativum* L.) as influenced by various methods of Potassium humate - 4.5 application**” is my own first hand bonafide work carried out by me under the guidance of **Dr. A.S. Gontia**, at Department of Plant Physiology, College of Agriculture, Jabalpur and place during 2013 - 2015.

The matter embodied in the thesis has not been submitted for the award of any other degree / diploma. Due credit has been made to all the assistance and help.

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## CURRICULUM VITAE

The author of this thesis **Mr. Dhanraj Patel** S/o Dharam Singh was born 16<sup>th</sup> Jun, 1988 at Sehore (M.P.). He passed the High School Examination in the year 2004 with 50.0 percent marks from Govt. High School, Bhaunkhedi, Sehore (M.P.) and Higher Secondary Examination in the year 2007 acquiring 64.22 percent marks from Higher secondary School Certificate Examination from, Gyan Darshan H. S. School, Bhaunkhedi, District Sehore (M.P)



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For the partial fulfillment of the master's degree programme he was allotted a research problem on "**Morpho-physiological traits and productivity in Garden Pea (*Pisum sativum* L.)** as influenced by various methods of Potassium humate - 4.5 application" which was successfully conducted by his and being submitted in the form of this thesis.

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## ABBREVIATIONS

%	-	Percentage
ha <sup>-1</sup>	-	Per hectare
@	-	At the rate of
°C	-	Degree centigrade
CD	-	Critical Difference
cm	-	Centimeter
DAS	-	Days after sowing
et al.	-	And others
Fig.	-	Figure
g	-	Gram
ha	-	Hectare
i.e.	-	That is
K	-	Potassium
kg	-	Kilogram
m	-	Meter
max	-	Maximum
min	-	Minimum
mm	-	Milimeter
N	-	Nitrogen
P	-	Phosphorus
q	-	Quintal
Rs	-	Rupees
t	-	Tonne
viz.,	-	Namely
Kg	-	Kilogram

## INTRODUCTION

Garden pea (*Pisum sativum* L.) belongs to the family Leguminosae which is comprised of three subfamilies and approximately 15,000 species that exhibit diverse morphology, habitat and ecology (Denarie et al., 1992). Pea is an important rabi pulse crop of India and known as common name Matar (Hindi, Nepali) Pea; Field pea, Split pea, Garden pea, Seed pea, Shelling pea, Combining pea, Forage or fodder pea, Dry pea, Feed pea, Vining pea (English). Pea was among the first crop cultivated by man which is highly productive, grown for food, forage and vegetable. There are two types grown pea in India, the garden pea (*Pisum sativum* var. hortense) is a green coloured, wrinkled seeded sweet in taste, used for table and canning purposes and young green pods are plucked. Another type of pea is grain type used for pulse and popularly known as field pea (*Pisum sativum* var. arvense). The seeds are round or little angular, hard and whitish in colour. The plants are very hardy and resistant to drought and frost. The sweet pea is another type of pea which has ornamental properties. The plants are tall, twining and bear very fragrant flowers. This type has little or no economic value.

Pea is an important frost-hardy, cool-season, nutritious leguminous vegetable that is widely cultivated throughout the world. As a cool season crop, it is extensively grown in temperate zone; but it is restricted to cooler altitudes in the tropics and winter season in the sub-tropics. It is a rich source of protein, amino acids, sugars, carbohydrates, vitamins A and C, calcium and phosphorus, besides having a small quantity of iron. Peas being very rich in proteins are valuable for vegetable purposes. Pea is an annual herbaceous plant of leguminous crop. The plants are succulent, erect (garden pea) with a plant height of 30-45 cm in garden pea and 50-75 cm in case of field peas. Garden peas being erect, remains erect while field peas have a tendency to climb when provided with a support. Plants bear tap root system with nodules on the surface. Stems are hollow, slender, succulent and ridged. It bears pinnately compound leaves with 3 pairs of leaflets and terminal one is modified into branched tendril. At the base of the petiole a large pair of stipule

or bracts is found and they cover the petioles in such a way that leaves look like sessile. The flowers are arranged in the form of an axillary raceme. The flowers may be reddish, purple or white. They are self-pollinated and develop into 5-9 cm long, inflated or cylindrical pods containing 5-11 seeds inside them. Seeds are angled, smooth or wrinkled, whitish, gray, green, or brownish; 100 seeds can weigh from 10 to 36 grams. Peas are also an excellent source of fibers and minerals (McPhee, 2004). The protein content of wrinkled-seeded pea cultivars is 26 -33 % while the protein in their smooth seeded counterparts is 23 - 31% (Cousin, 1997).

Pea is the fourth leading legume in terms of consumption in the world and an important vegetable and field crop of India. Total area of pea in the country is 420.9 thousand hectare with the production of 4006.2 thousand metric tonnes and productivity of this crop 9.5 in metric tonnes per hectare while in Madhya Pradesh this crop covers is 53.45 thousand hectare with the production of 534.00 thousand metric tonnes and productivity of this crop 10.00 in metric tonnes per hectare (Anonymous, 2013).

Potassium humate is a complex organic molecule formed by the breakdown of organic matter in soil by microorganisms and it is not a fertilizer. It is found in forest soil 2% - 3% and rich in oxidized low rank coal, lignite, peat etc., major constituents of carbon and oxygen about 90%. Using Potassium humate has a variety of benefits and it is applicable for all type of crops. It is a root growth promoter, increases chlorophyll content, enhances plant growth particularly biomass production, improves plant quality, good plant growth stimulant. It increases nutrient uptake, acting on soil and plants. Our land lost its fertility due to prolonged and excess use of chemical fertilizers and pesticides. It improves physical property of soil, ion exchange capacity, water holding capacity and drought tolerance ability. This also prevents loss of nutrients from soil and act as a storehouse by keeping plant nutrients in soil. It increases crop yield and reduces the use of pesticide and chemical fertilizers. Our Indian soils are low in organic carbon. Due to intensive cultivation, organic matter and other nutrients are depleted from the soil. To compensate this, traditionally organic manure, composite, vermin compost and green manure are used in large quantities to achieve humic acid content in the soil.

Application of Potassium humate helps to build up organic matter content in the soil, enhancing water retention, cation exchange capacity, plant growth stimulant and helps to improve the yield of crops. Chemical composition of humic acid (HA) Soluble Potassium humate: 80 % humic acid, 11-13 % K<sub>2</sub>O, 5-7 % moisture, 83 g/100ml bulk density, > 98 % water solubility.

Potassium humate a product of humic acid increases the release of primary macronutrients (N, P and K). Nitrogen is released significantly up to 20 kg humic acid ha<sup>-1</sup>, while phosphorus and potassium up to 40 kg humic acid ha<sup>-1</sup>. The release of nitrogen and phosphorus took longer period of 60 days while potassium was released for relatively shorter period of 45 days after incubation. Organic carbon and cation exchange capacity were significantly increased at the end of incubation period (Sathiya et al., 2003). Application of humic acid increased soil acidity, soil organic carbon and cation exchange capacity (Hanafi and Salwa, 1998). Humic acid is one of the important sources of organic matter in soil (Chen and Aviad, 1990).

Therefore the application of humates was tested as an approach to improve both the nutrient balance and plant vitality (Boehme et al., 2005). Nevertheless, it is very important to stabilize the supply of macro elements; much more essential for plant growth in substrate culture is the sufficient supply with microelements, often there are disorders of them especially the problem of iron deficiency (Boehme et al., 2005). Foliar sprays of these substances also promote growth, increases yield and quality in a number of plant species (Yildirim, 2007; Karakurt et al., 2009). At least partially through increasing nutrient uptake, Likewise, humic substances have been shown to stimulate shoot and root growth and nutrient uptake of vegetable crops (Tattini et al., 1990; Padem et al., 1997; Cimrin and Yilmaz, 2005). Humates can stimulate the uptake of macro- and microelements (Tattini et al., 1990). At low concentrations, humic substances enhance cell elongation in excised pea root segments, increases algal and microbial growth, but are inhibitory at higher concentrations (Bhardwaj and Gaur, 1970; Tan and Nopamornbodi, 1979; Vaughan, 1969). The humic acid promotes the uptake of N, P, Fe and Cu of tomato and other plants (Adani et al., 1998). Moreover, humates influence the respiration-process, the amount of sugars, amino acids, nitrate accumulated

and make the plants resistant against diseases and viruses (Boehme et al., 2005). It is assumed that humic acid has special importance for transportation and availability of microelements in the plants (David et al., 1994; Kreij and Hoeven, 1997). Applications of humic substances (HS) may help in achieving of increasing organic food production as HS applications are generally recommended in organic agriculture (Shahryari et al., 2009).

Though the Potassium humate is important growth stimulant, morpho-physiological traits contributing to productivity are not clearly understood in garden pea.

Keeping in view of the above the present investigations were conducted with the following objectives:-

1. Assessment of garden pea for phenophases, morpho-physiological traits, physiological efficiency, biomass partitioning and productivity under various methods of Potassium humate applications.
2. Quantification of growth analytical parameters, yield components, yields and biochemical constituents in garden pea under various methods of Potassium humate applications.

## REVIEW OF LITERATURE

A brief work carried out in different parts of world pertaining to the investigations has been summarized as follows:

### **2.1 Phenophases:-**

#### **2.1.1 Days to tendrill formation**

Armstrong and Patel (1994) reported that the poor growth of semi-leafless and tare-leaved types was attributed to increasing tendrill size.

#### **2.1.2 Days to 1<sup>st</sup> flower initiation**

Adhikari and Pandey (1982) noted that seed yield was positively and directly influenced by days to flower initiation in chickpea.

Bhattacharya and Sharma (2001) reported that the flower initiation is an important phenological stage which determines the plant productivity in pigeonpea.

Chaudhary and Sharma (2003) reported in pea the significant genetic variation among the F1 hybrids for the first flowering initiation.

Kumar et al. (2008) reported that the significant correlation between early days to flower initiation with yield would be more effective for improving green pod yield in garden pea.

Pal and Singh (2012) reported highly significant was difference in the genotypes for days to 1<sup>st</sup> flower emergence in garden pea.

Sharma and Sharma (2012) reported that in garden pea a high positive significant correlation of days to first picking with node number was noted at which first flower appear.

#### **2.1.3 Days to 50 % flowering**

Katore and Navale (2010) reported that the days to 50% flowering were the major yield-contributing characters and will help in improving the seed yield in garden pea.

Pal and Singh (2012) reported the highly significant difference in the genotypes for days to 50% flower emergence in garden pea.

Sharma and Sharma (2012) reported that in garden pea a high positive significant correlation of days to 50% flowering suggested that these genotypes were early flowering genotypes.

Kumar et al. (2013) reported in pigeon pea that the harvest index had high positive direct effect on days to 50% flowering.

#### **2.1.4 Days to pod initiation**

Pal and Singh (2012) reported highly significant difference in the genotypes for days to 1<sup>st</sup> pod set in garden pea.

#### **2.1.5 Days to 1st, picking**

Ramesh and Tewatia (2002) revealed that the number of pods plant<sup>-1</sup> had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea.

Kumar et al. (2003a) reported that the pod yield plant<sup>-1</sup> exhibited a significant and positive correlation with number of days to first picking.

Kumar and Sharma (2006) suggested that the greater emphasis should be given to characters like days to first green pod harvest.

#### **2.1.6 Days to Physiological maturity**

Eastin et al. (1973) observed that after physiological maturity the assimilates were not partitioned towards sink from the source, because vascular connection to the sink is broken by formation by abscission layer.

Gontia et al. (1995) reported that at physiological maturity in soybean genotypes 4-10.66 leaves/ plant were retained by the genotypes and the colour of the pods and stem became dark red brown to brown.

Poggio et al. (2005) reported that the effects of low temperatures on seed weight showed a negative response to mean temperature during the grain-filling phase.

### **2.1.7 Days to physical maturity**

Kumar et al. (2003) reported that the days to maturity showed a significant association with 100-grain weight and number of seeds pod<sup>-1</sup>.

Kumar et al. (2008) reported that the green pod yield plant<sup>-1</sup> was positively and significantly correlated with days to maturity.

Katore and Navale (2010) reported that the days to maturity was the major yield-contributing characters and will help in improving the seed yield in garden pea.

Kumar et al. (2012) reported that the seed yield plant<sup>-1</sup> had the significant and negative association with days to maturity.

Pal and Singh (2012) reported the highly significant difference in the genotypes for days to maturity of edible green pod in garden pea.

Kumar et al. (2014) reported that the seed yield plant<sup>-1</sup> was found to be significantly and positively correlated with days of maturity.

Shadakshari et al. (2014) reported in soybean that among morphological traits under water stress conditions, the days to maturity showed the maximum reduction (94%).

## **2.2 Physiological observations:-**

### **2.2.1 Dry matter production and partitioning**

#### **2.2.1.1 Leaves dry weight**

Singaroval et al. (1993) reported that the humic acid increased dry matter production might be due to its direct action on plant growth auxin activity, contributing to increase in the leaves dry matter in pea.

Gad El-Hak (2012) reported that the foliar application with humic acid @2 g L<sup>-1</sup> increased leaves dry weight in the two growing seasons.

#### **2.2.1.2 Stem dry weight**

Singaroval et al. (1993) reported that the humic acid increased dry matter production might be due to its direct action on plant growth auxin activity, contributing to increase in the stem dry matter in pea.

Senesi and Loffredo (1994) reported that in peas stem dry weight recorded the highest values by foliar application with humic acid @ of 100 mg+herbicides.

Padem et al. (1999) suggested that the stem dry weight was significantly increased by foliar spray with humic acid @1.0gL<sup>-1</sup> in eggplant.

Bange and Milroy (2004) noted that timing of crop maturity is largely determined by the capacity of the plant to continue the production of new fruiting sites, stem dry matter production could be impinged both on the timing of crop maturity and yield.

Ashraf et al. (2005) observed the significant effect on stem dry matter of mungbean with the application of HA as soil application.

Gad El-Hak (2012) reported that the foliar application with humic acid@2 g L<sup>-1</sup> increased stem dry weight in the two growing seasons.

#### **2.2.1.3 Tendril dry weight**

Armstrong and Patel (1994) reported that the total net photosynthesis of the tendrils of semi-leafless types was similar to that of leaflets of conventional types, due to larger dry weight of tendrils compensating for poor photosynthetic rates.

#### **2.2.1.4 Pod dry weight**

Singaroval et al. (1993) reported that the humic acid increased dry matter production might be due to its direct action on plant growth auxin activity, contributing to increase the pod dry matter in pea.

Senesi and Loffredo (1994) reported that in peas pod dry weight recorded the highest values by foliar application with humic acid at the rate of 100 mg+herbicides.

Padem et al. (1999) suggested that the pod dry weight was significantly increased by foliar spray with humic acid @ of 1.0 g L<sup>-1</sup> in eggplant.

Ntanos et al. (2002) noted that the dry matter accumulation was greater for short and later maturing cultivars compared to the tall and early

maturity or mid-season cultivars. Grain yield was positively and significantly correlated with pod dry matter accumulation.

Ashraf et al. (2005) observed the significant effect on pod dry matter of mungbean with the application of HA as soil application.

Jun et al. (2006) reported the positive correlation between yield and dry matter accumulation in seeds.

Gad El-Hak (2012) reported that the foliar application with humic acid @2 g L<sup>-1</sup> increased highest pod dry weight in the two growing seasons.

#### **2.2.1.5 Total dry weight**

Senesi and Loffredo (1994) reported that in peas total plant dry weight exhibited the highest values by foliar application with humic acid @100 mg+herbicides.

Padem et al. (1999) observed that the total plant dry weight was significantly increased by foliar spray with humic acid @1.0 g L<sup>-1</sup> in eggplant.

Timmannavar and Patil (2000) noted that the total dry matter production by a crop may vary according to the changes in either the size of photosynthetic system or in its activity, as well as in the length of the growth period during which photosynthesis continues.

Ashraf et al. (2005) observed the significant effect on total dry matter of mungbean with the application of HA as soil application.

Karim and Fattah (2007) reported that the total dry weight was increased in all vegetation period in chickpea.

Gavit et al. (2008) reported in garden pea that the highest yield among the genotypes was due to higher total dry matter.

Gad El-Hak (2012) reported that the foliar application with humic acid @ 2 g L<sup>-1</sup> with increased highest total dry weight in the two growing seasons.

Rao et al. (2012) reported that plant dry matter accumulation depends on the total C fixed during photosynthesis and the action of the carbon converted into dry matter.

Munakamwe et al. (2012) noted that the increased pea sowing rates increased total dry matter.

Motaghi et al. (2014) reported in cowpea that the total dry weight was significantly increased at the concentration of 100 ppm humic acid and 300 kg ha<sup>-1</sup> potassium.

## **2.2.2 Growth parameters**

### **2.2.2.1 LAI (Leaf Area Index)**

Watson (1952) observed that the increase in dry matter is associated with increase in LAI to a stage where the mutual shading of leaves does not take place after that with increasing LAI the dry matter accumulation decreases.

Singh et al. (1976) noticed that leaf size, number and area, in spite of ample variation for leaf characteristics, it has not been quantified and studied for relationships with growth and yield attributes in pigeonpea.

Deshmukh and Patil (1995) noted the significant positive correlation values for mean LAI with CGR. This indicates the importance of leaf area in increasing the rate of photosynthesis.

Timmannavar and Patil (2000) observed that the leaf photosynthetic rate and leaf area index appeared to be major determinants of crop growth rate.

Rajput et al. (2004) found that the differences in the leaf area index of the genotypes examined were not significant. Leaf area index ranged from 0.54 to 3.17.

Jamil et al. (2006) reported in garden pea that the cultivar and sowing date affected significantly the leaf area index (LAI).

Kumar and Sharma (2006) suggested that the greater emphasis should be given to characters like leaf area index.

Karim and Fattah (2007) reported that the LAI (Leaf Area Index) was increased up to pod filling period in chickpea.

Gavit et al. (2008) reported in garden pea that the highest yield among the genotypes was due to higher leaf area index.

#### **2.2.2.2 Leaf Area Duration**

Singh and Agarwal (2001) noted that the senescence of leaves at maturity reduced the CGR, LAI, and LAD and consequently the rate of dry matter accumulation.

Karim and Fattah (2007) reported that the LAD (Leaf Area Duration) was decreased to first pod setting in chickpea.

#### **2.2.2.3 Crop Growth Rate**

Srivastava and Singh (1980) revealed comparatively higher CGR in podding stage than in early growth stage in different varieties.

Warren and Wilson (1981) concluded that CGR can be analyzed as the product of incident light receipt efficiency of light penetration and efficiency of use of intercepted light in dry matter production.

Srivastava and Singh (1989) reported in garden pea that a significantly higher CGR, the leaf area ratio showed a similar trend but the RGR and NAR were higher in Arkel. No definite pattern with regard to sowing dates was observed. Variations in different growth parameters were more common during the period between full bloom to 50% pod harvest than between 30 days after sowing to full bloom.

Pal et al. (1996) noted that crop growth rate gradually increases with crop age and reached its peak during 70 to 90 days, thereafter declined.

Tiwari et al. (1996) reported that CGR increased highly with advancement in plant age but decreased at ripening.

Shiraiwa et al. (2004) reported that the yield significantly and positively correlated with crop growth rate (CGR) during the 20 d period after the beginning of seed filling (R5), i.e. initial seed filling stage. The correlation of seed yield with CGR varied with the year from negative to positive correlations.

Jamil et al. (2006) reported in garden pea that the cultivar and sowing date affected significantly the crop growth rate.

Karim and Fattah (2007) reported that the CGR (Crop Growth Rate) was increased to pod filling period in chickpea.

Gavit et al. (2008) reported in garden pea the highest yield among the higher crop growth rate.

Patil et al. (2010) noted the potassium humate treated plants showed more vegetative growth than control plants (untreated plants).

#### **2.2.2.4 Relative Growth Rate**

Mahon (1990) reported that the higher planting density decreased relative growth rate by 24%.

Sarkar et al. (2004) noted that the RGR varied significantly in all the tested varieties. Though the genotypes differ in the yield potentiality, the varieties being within the same species did not vary significantly among each other with respect to RGR.

Jamil et al. (2006) reported in garden pea that the cultivar and sowing date affected significantly the relative growth rate (RGR).

#### **2.2.2.5 Specific leaf area**

Sahoo and Guru (1998) observed positive association of LAI, CGR and SLA with grain yield.

### **2.3 Other physiological traits and mechanism:-**

#### **2.3.1 Chlorophyll content index**

Choudhary et al. (1994) noted that the grain development was accompanied by decreases in chlorophyll contents of the leaf as a result of ageing.

Kongjika and Mathis (1995) concluded that the chlorophyll a/b ratio was correlated with photosynthesis efficiency.

Ladygin (2003) reported in pea in stem and leaf colour relative chlorophyll contents approximately 80 and 50%, respectively.

Sakalauskiene et al. (2008) reported in pea that the high temperature and the lack of humidity also inhibited the synthesis of chlorophylls a and b.

Betzelberger et al. (2010) reported that the chlorophyll content was positively correlated with seed yield.

### **2.3.2 Quantum efficiency**

Pandey et al. (2001) reported that quantum yield increased maximum with IAA under field capacity. It decreased with increasing duration of water logging.

Isoda and Tomagae (2003) observed non significant differences between the treatments in quantum yield of photosystem II (Phi PSII) and non-photochemical quenching (NPQ) except 16 Aug., which are concerning with the efficiency and photoinhibition in PSII, respectively.

### **2.3.3 Carboxylation efficiency**

Natraja and Jacob (1999) reported that the carboxylation efficiency differed significantly among the clones and the clones such as K<sub>37</sub>, T<sub>6</sub>, T<sub>21</sub> and K<sub>4</sub> which had high CE also showed relatively higher WUE.

Hamerlynck et al. (2000) noted that the ratio of net photosynthesis rate to intercellular CO<sub>2</sub> concentration is termed as intrinsic carboxylation efficiency, higher ratio better the efficiency for carboxylation.

Gilbert et al. (2011) observed that the maximal rate of Rubisco carboxylation, generally the limiting photosynthetic process for soybeans, was correlated with photosynthetic capacity.

Soundararajan (2012) reported that decreased leaf carbon isotope fractionation with increased Chl levels suggests an enhanced carboxylation capacity in these leaves.

### **2.3.4 Water use efficiency**

Richards et al. (2001) observed that the water use and water use efficiency are critical parameters where water is scarce in pigeonpea crop. The use of less water to achieve high yield is a major object of the modern agriculture.

Siddique et al. (2001) reported in pea that the large yields in the dry matter production allow greater water use efficiency in the post flowering period.

Earl (2002) observed that the higher WUE are often found to maintain lower leaf internal CO<sub>2</sub> concentration (ci), as estimated by carbon isotope

discrimination. However, lower  $c_i$  may result from reduced stomatal conductance, increased mesophyll (non-stomatal) conductance, or a combination of both. When genotypic variation for WUE is found, it may be important for plant breeding purposes to define whether such variation arises from differences in stomatal or non-stomatal restrictions to  $\text{CO}_2$  uptake.

### **2.3.5 Mesophyll efficiency**

Ramanjulu et al. (1998) reported that at given stomatal conductance, lower  $C_i$  indicated better mesophyll efficiency and better draw down rate of the substrate  $\text{CO}_2$ .

Liu et al. (2012) noted that the yield was positively correlated with mesophyll conductance.

### **2.3.6 Canopy temperature**

Manzanares et al. (1998) reported in pea cultivars that the epicuticular wax content, cuticular transpiration and leaf colour reduce the canopy temperature.

Kumar et al. (2006) reported that the high temperatures during the reproductive phase significantly reduced the number of seeds per pod. The photothermal unit received during the vegetative stage had a significant positive correlation with yield, while during the reproductive phase of the crop; it had a significant negative correlation with yield, pods per plant and seeds  $\text{pod}^{-1}$ .

Sakalauskiene et al. (2008) reported that the temperature regime on pea significantly influenced plant physiological processes.

### **2.3.7 Photosynthesis Active Radiation absorption**

Monteith and Elston (1983) noted that the analysis of crop growth should consider total dry matter (IDM) as a product of the amount of photosynthetically active radiation (PAR) intercepted by the crop multiply by an efficiency factor. Such analysis suggests that reduction utilization efficiency is a conservative quantity.

Saini and Nanda (1986) observed that the agriculture is basically a system of exploitation of solar radiation through photosynthesis and the amount of intercepted photosynthetic photon flux density (wavelength 400 to 700 nm) has direct relation with leaf area development.

Jarwal and Singh (1990) noted that since the photosynthesis is the corner stone of crop production, it is important to be aware of the energy available to drive photosynthesis process and to know the interception of photosynthetically active radiation at different crop phenological stages in relation to crop growth or biomass production.

Haloj and Dey (2000) noted that the variation in productive efficiency between rice cultivars and plant population stress under a given set of environment depends on the rate at which a closed canopy develops leading to better use of incoming solar radiation.

Wall and Kanemasu (2000) noted that the relationship between the daily net and gross canopy CO<sub>2</sub> exchange rate and daily absorption of PAR were linear. Higher daily net and gross CO<sub>2</sub> exchange rates phyto-mass in the narrow spaced canopy were attributed to a greater quantity of daily absorbed PAR through the season, rather than difference in the efficiency of the various canopy structures.

Mukherjee and Sastri (2003) noted the maximum PAR interception during fruit development stage of the crop.

Lama et al. (2003) observed that BG362, K850 and Annegiri intercepted higher percentage of photosynthetic active radiation (PAR) compared to the other 3 cultivars in chickpea under both irrigated and unirrigated conditions at the maximum leaf area index (LAI) stage. The intercepted PAR was closely related to biomass production.

Akhter et al. (2005) reported that the chlorophyll a and b were at minimum level under 100% PAR, which increased with reducing light intensity. At 25% PAR the highest chlorophyll a content was found in P 52 (1.8mg/g). The highest chlorophyll b content was recorded at 25% PAR in all genotypes except genotype IPSA3. At 25% PAR the highest amount of chlorophyll b.

### **2.3.8 Net Photosynthesis Rate**

Ojma et al. (1969) reported that crop yields depends upon both the rate and duration of photosynthesis and increased photosynthesis potential is considered to be a possible approach in improving yield.

Fischer et al. (1998) reported that the higher productivity of semi dwarf wheat cultivars has been attributed to their greater leaf photosynthetic rate.

Munier-Jolain et al.(1998) reported that the maximum growth rate of seeds was achieved regardless of the intra-plant competition level and the duration of seed growth was shortened if the photosynthetic activity was not sufficient to fulfil the assimilate demand of filling seeds in grain legumes.

Natraja and Jacob (1999) reported that net photosynthesis rate (pn) is the important factor that determines the biomass production and water use efficiency of a species. Variation in Pn photosynthesis has been reported as determinants of plant productivity.

Georgieva et al. (2000) reported in pea that the photosynthetic activity decreased sharply after 24 h at 45 degrees C.

Kalpana et al. (2003) reported in cowpea that the photosynthetic rate is maximum at the flowering stage and declined at the pod development stage.

Delfine et al. (2005) reported that the humic acid had limited promoting effects on photosynthetic metabolism of durum wheat crops grown.

Shah et al. (2010) Noted that the impact of soil moisture deficit on carbon assimilation was found be severe even under mild stress due to the damage it causes to the photosynthetic machinery and the photoinhibition due to decreasing leaf torgor.

Liu et al. (2012) noted that the yield was positively correlated with net photosynthetic rate (Pn). The Pn and Pn/Ci are the effective selection indexes for seed yield and can be used in future breeding programs.

### **2.3.9 Stomatal conductance**

Hsiao (1973) reported that photosynthesis is largely depends on stomatal regulation.

Ackerson et al. (1980) noticed significant difference in stomatal conductance when leaf water potential was high.

Beadle et al. (1981) reported that the stomatal conductance is of utmost importance when photosynthesis is concerned. Stomata play a pivotal role in controlling the balance between assimilation and transpiration.

Kumar et al. (1998) observed that the stomatal conductance (SC) and transpiration rate (TR) although possessed significant positive association with photosynthesis rate their associations with grain yield was not significant.

Anyia and Herzog (2003) showed that drought caused a reduction in stomatal conductance. Reductions in leaf water potential as a consequence of drought positively correlated with a decline in assimilation rate, which was associated with stomatal closure.

Zhao et al. (2003) reported that reduction in transpiration rate and stomatal conductance and concomitant increase in intercellular CO<sub>2</sub> concentration suggests that both stomatal factors were involved in the reduction of photosynthesis.

Delfine et al. (2005) reported that the foliar application of humic acid did not affect stomatal conductance.

Burman et al. (2011) observed that the water stress induced decline in PN was accompanied with a significant and drastic reduction in stomatal conductance. The stomatal conductance by virtue of its effect on movement of carbon dioxide and water vapor across leaf affects transpiration, water balance and photosynthesis throughout the growing period.

### **2.3.10 Transpiration Rate**

Farquhar and Sharkey (1982) reported that it is necessary to have higher plant conductance to achieve higher canopy photosynthesis which would lead to higher canopy photosynthesis and higher biological yield. It should be borne in mind that high plant conductance rate not only enhance the CO<sub>2</sub> exchange rate but also results in higher transpiration rate.

Taiz and Zeiger (2002) reported that the transpiration is one of the major gas exchange parameters associated with plant growth and productivity.

Kalpna et al. (2003) reported in cowpea that the transpiration rate is maximum at the flowering stage and declined at the pod development stage.

Gupta et al. (2012) reported that rate of transpiration decreased with the advancement of maturity. It might have occurred on account of the cumulative effect of decreased soil moisture content.

## **2.4 Yields and yield components:-**

### **2.4.1 Plant height**

Armstrong and Patel (1994) reported that the poor growth of semi-leafless and tare-leaved types was attributed to increasing shoot height.

Chaudhary and Sharma (2003) reported in pea the significant genetic variation among the F1 hybrids for the plant height.

Kumar and Sharma (2006) stressed that the greater emphasis should be given to characters like plant height.

Kumar et al. (2008) reported in pea that the green pod yield per plant was positively and significantly correlated with plant height.

Pal and Singh (2012) reported the highly significant variation in the genotypes for plant height in garden pea.

Kumar et al. (2014) reported that the seed yield per plant was found to be significantly and positively correlated with plant height.

### **2.4.2 Number of nodes plant<sup>-1</sup>**

Armstrong and Patel (1994) reported that the poor growth of semi-leafless and tare-leaved types was attributed to increasing number of node per plant.

Ramesh and Tawatia (2002) revealed that the number of pods per plant had maximum direct genotypic effect on number of nodes per plant; these traits should be for the yield improvement in garden pea.

Kosev and Mikic (2012) reported the highest positive indirect effect of number of fertile nodes per plant (12.58) on seed yield in field pea.

### **2.4.3 Number of pods plant<sup>-1</sup>**

Shah and Lal (1992) reported that in pea pods/plant had the greatest direct and indirect effects on green pod yield.

Moot and McNeil (1995) noted that the number of pods per plant was highest when each genotype was grown as spaced plants.

Golaszewski and Puzio-Idzkowska (1996) reported in field pea that the pods plant<sup>-1</sup> had the greatest direct and indirect effects on green pod yield.

Singh and Singh (1996) estimated that the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for pods per plant.

Musaana and Nahdy (1998) reported that the phenotypic and genotypic correlations indicated that the number of pods plant<sup>-1</sup> had the greatest direct effects on yield in pigeonpea.

Ramesh and Tewatia (2002) revealed that the number of pods per plant had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea.

Chaudhary and Sharma (2003) reported in pea the significant genetic variation among the F1 hybrids for the number of pods per plant.

Kumar et al. (2003) reported that the pod yield per plant exhibited a significant and positive correlation with number of pods per plant.

Kumar and Sharma (2006) suggested that the greater emphasis should be given to characters like number of pod per plant.

Kumar et al. (2008) reported that the green pod yield per plant was positively and significantly correlated with number of pods per plant.

Gavit et al. (2008) reported in garden pea that the highest yield among the genotypes was due to higher number of pods per plant.

Togay et al. (2008) reported that the positive and significant relationship among seed yield, pods per plant and biological yield in pea.

Guleria et al. (2009) reported that the higher number of pods increased the grain yield in pea.

Tripathi et al. (2011) found in dwarf field pea significant positive correlation of seed yield only with number of pods plant<sup>-1</sup> ( $r=0.664$ ).

Kumar et al. (2012) reported that the seed yield per plant possessed the significant and positive association with number of per plant<sup>-1</sup>.

Pal and Singh (2012) reported the highly significant difference in the genotypes for number of pods plant<sup>-1</sup> in gardenpea.

Kumar et al. (2014) reported that the seed yield plant<sup>-1</sup> was found to be significantly and positively correlated with pods plant<sup>-1</sup>.

Muhammad et al. (2014) reported that the humic acid application at the rate of 3 kg ha<sup>-1</sup> significantly resulted in higher number of pods plant<sup>-1</sup> in mungbean.

#### **2.4.4 Number of seeds pod<sup>-1</sup>**

Shah and Lal (1992) reported that in pea seed number plant<sup>-1</sup> showed a significant direct effect on seed yield.

Singh and Malik (1994) reported in pea that the seeds pod<sup>-1</sup> were directly correlated with seed yield plot<sup>-1</sup>.

Moot and McNeil (1995) noted that the number of seeds pod<sup>-1</sup> was highest when each genotype was grown as spaced plants.

Musaana and Nahdy (1998) reported that the phenotypic and genotypic correlations showed that the number of seeds pod<sup>-1</sup> had the greatest direct effects on yield in pigeonpea.

Jain and Kurchavia (2002) found that number of seeds pod<sup>-1</sup> was positively and significantly correlated with seed yield.

Ramesh and Tewatia (2002) revealed that the number of pods plant<sup>-1</sup> had maximum direct genotypic effect on grain weight pod<sup>-1</sup>. These traits should be for the yield improvement in garden pea.

Kumar et al. (2003a) reported that the number of days to maturity showed a significant association with number of seeds pod<sup>-1</sup>.

Kumar et al. (2003b) reported that the pod yield per plant exhibited a significant and positive correlation with number of edible grains pod<sup>-1</sup>.

Onemi (2003) found that the plant yield reported positive and significant correlation with number of seeds pod<sup>-1</sup>.

Kumar and Sharma (2006) stressed that the greater emphasis should be given to characters like number of grains pod<sup>-1</sup>.

Gavit et al. (2008) reported in garden pea that the highest yield among the genotypes was due to higher number of grains pod<sup>-1</sup>.

Katore and Navale (2010) reported that the seed number pod<sup>-1</sup> was the major yield contributing characters and will help in improving the seed yield in garden pea.

Pal and Singh (2012) indicated the highly significant variation in the genotypes for number of seeds pod<sup>-1</sup> in garden pea.

Udens and Ikpeme (2012) reported that the leaf area plant<sup>-1</sup> had a positive significant association with the number of seeds plant<sup>-1</sup> (0.58).

#### **2.4.5 100 seed weight**

Singh and Malik (1994) reported in pea that the 100-seed weight was directly correlated with seed yield plot<sup>-1</sup>.

Musaana and Nahdy (1998) reported that the phenotypic and genotypic correlations indicated that seed weight had the greatest direct effect on yield in pigeon pea.

Kumar et al. (2003) reported that the number of days to maturity showed a significant association with 100-grain weight.

Gavit et al. (2008) reported in garden pea that the highest yield among the genotypes was due to higher 100-grain weight.

Katore and Navale (2010) reported that the 100-seed weight was the major yield contributing character and helps in improving the seed yield in garden pea.

Kosev and Mikic (2012) reported in field pea that the direct positive effect on seed yield was found in 100-seed weight (5.92).

Kamran et al. (2014) reported that the Humic acid levels possessed no significant effect on thousand grains weight.

Kumar et al. (2014) reported that the seed yield plant<sup>-1</sup> was found to be significantly and positively correlated with seed index.

Muhammad et al. (2014) reported that the Humic acid application at the rate of 3 kg ha<sup>-1</sup> significantly resulted in higher thousand grain weight in mungbean.

#### **2.4.6 Pod length**

Shah and Lal (1992) reported that in pea pod length showed a significant direct effect on seed yield.

Golaszewski and Puzio-Idzkowska (1996) reported in field pea that the pod length showed a significant direct effect on seed yield.

Kumar et al. (2003b) reported that the pod yield per plant exhibited a significant and positive correlation with pod length.

Katore and Navale (2010) reported that the pod length was the major yield-contributing character and will help in improving the seed yield in garden pea.

Muhammad et al. (2013) reported that the pod length showed positive but no significant correlation with yield in pea.

Kumar et al. (2014) reported that the seed yield plant<sup>-1</sup> was found to be significantly and positively correlated with pod length.

#### **2.4.7 Pod width**

Muhammad et al. (2013) reported that the pod width showed positive but no significant correlation with yield in pea.

#### **2.4.8 Green pod yield**

Sarnaik et al. (1990) reported that the number of green pods plant<sup>-1</sup> had the highest positive direct effect on green pod yield in pea.

Rana and Gupta (1994) reported that the green pod yield and phenological traits in *Pisum sativum* were highly significant. Green pod yield was influenced by over dominance.

Ramesh and Tewatia (2002) revealed that the number of pods per plant had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea.

Chamundeswari (2003) observed that seed yield had positive correlation with pod yield plant<sup>-1</sup>.

Kumar et al. (2003b) reported that the pod yield per plant exhibited a significant and positive correlation with mean pod weight.

Kumar and Sharma (2006) suggested that the greater emphasis should be given to characters like green pod yield plant<sup>-1</sup>.

Kumar et al. (2008) reported that the green pod yield plant<sup>-1</sup> was positively and significantly correlated with number of pods per plant. Days to marketable maturity, plant height, crude protein and days to flower initiation would be more effective for improving green pod yield.

Pal and Singh (2012) reported the highly significant variation in the genotypes for green pod yield plant<sup>-1</sup> in gardenpea.

#### **2.4.9 Seed yield**

Alsadon and Khalil (1994) reported in the peas cv. Lincoln and Rondo were sown early (21-22 Oct.), mid-season (4-6 Nov.) or late (18-19 Nov.), the yield was not significantly different between cultivars and was highest with the mid-season sowing date.

Singh and Malik (1994) reported in pea that the seed yield plant<sup>-1</sup> was directly correlated with seed yield plot<sup>-1</sup>.

Singh and Singh (1996) estimated that the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for seed yield plant<sup>-1</sup>.

Manzanares et al. (1998) reported in pea cultivars that the epicuticular wax content has a beneficial effect on seed yield under rain fed conditions.

Delfine et al. (2005) reported that the Humic acid had limited promoting effects on plant growth, grain yield and quality of durum wheat crops grown.

Togay et al. (2008) reported the positive and significant relationship among seed yield, pods plant<sup>-1</sup> and biological yield in pea.

Guleria et al. (2009) noted that the higher number of flowers, pods and seeds pod<sup>-1</sup> should be selected to increase the grain yield in pea.

Shahryari et al. (2009) noted that the applications of potassium humate increased the average grain yield from 2.49 to 3.61 ton ha<sup>-1</sup> under normal irrigation scheme in wheat.

Patil et al. (2010) reported that the vegetative characters of plants, potassium humate treated plants showed more vegetative growth than control plants (untreated plant).

Patil et al. (2011) reported that the Potassium humate treated plants showed significantly increased on growth and yield characters of soybean and black gram than control plants.

Munakamwe et al. (2012) noted that the increased pea sowing rates increased seed yield.

Kamran et al. (2014) reported that the Humic acid levels significantly increased grain yield ha<sup>-1</sup>.

Muhammad et al. (2014) reported that the Humic acid application at the rate of 3 kg ha<sup>-1</sup> significantly resulted in higher grain yield in mungbean.

#### **2.4.10 Biological yield**

Sirohi et al. (2006) reported that the biological yield per plant showed highest and significant association with harvest index (0.628\*) at phenotypic level in garden pea.

Togay et al. (2008) reported that the positive and significant relationship was found among seed yield and pods plant<sup>-1</sup> and biological yield in pea.

Muhammad et al. (2014) reported in mungbean that the biological yield was not significantly affected by humic acid application methods.

#### **2.4.11 Harvest Index**

Singh and Singh (1996) estimated that genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for harvest index.

Manzanares et al. (1998) reported in pea cultivars that the epicuticular wax content is associated with turgor pressure maintenance through osmotic adjustment increases harvest index.

Siddique et al. (2001) reported in pea that the large yields were due to greater partitioning of dry matter into seed, which is reflected in greater harvest index.

Khan et al. (2004) reported in chickpea that the harvest index and economic yield had significant positive correlation value of ( $r = +0.595$ ), while negative correlation value of ( $r = -0.435$ ) was observed between harvest index and biological yield.

Sirohi et al. (2006) reported that the biological yield per plant showed highest and significant association with harvest index ( $0.628^*$ ) at phenotypic level in garden pea.

Kumar et al. (2013) reported in pigeon pea that the harvest index had high positive direct effect on seed yield followed by biological yield plant<sup>-1</sup>.

Shadakshari et al. (2014) reported in soybean that the water stress conditions reduced harvest index (69%).

## **2.5 Proximate analysis:-**

### **2.5.1 Protein**

Borowska et al. (1998) noticed that the large varieties were concentrations of protein 20.75% in DM (Granit) to 31.09% in DM (Sol).

Maciejewicz-Rys and Slusarczyk (2001) reported that the crude protein content (% DM) ranged from 21.5-24.9 in fodder pea varieties and from 21.7-26.3 in edible varieties.

Stanek et al. (2004) reported that the white-flowering peas seeds contained more crude protein (22.03 vs. 20.99%).

Habashy et al. (2005) reported that the foliar application with humic acid @ of 2 g L<sup>-1</sup> gave significant increases in protein % also it compared with the control treatment.

Sirohi et al. (2006) reported in garden pea that the seed yield showed positive and significant association with protein percentage ( $0.458^*$ ).

Kumar et al. (2008) reported that the green pod yield per plant was positively and significantly correlated with crude protein.

Guleria et al. (2009) reported the significant varietal variations in the mature dry seeds of pea genotypes of total protein (14.95% to 22.44%).

Gupta and Mahajan (2010) reported that the biochemical analysis of total seed proteins in 8 pea genotypes ranged from 16.3-20.4% with highest protein content (20.4%) exhibited by control Arkel.

Kotlarz et al. (2011) noted that the cropping year had a significant influence on crude protein.

Gad El-Hak (2012) reported that the foliar application with humic acid @2 g L<sup>-1</sup> increased protein % of dry seeds the two growing seasons.

### **2.5.2 Carbohydrates**

Borowska et al. (1998) noticed that the large varieties were concentrations of starch 47.13% in DM (Amethyst) to 65.53% in DM (Karat).

Ramesh and Tewatia (2002) revealed that the number of pods per plant had maximum direct genotypic effect on total sugars in edible grain.

Patil et al. (2013) reported that the potassium humate treated plants showed significant increase in carbohydrate of wheat than control plants (untreated plant).

### **2.5.3 Fibre**

Borowska et al. (1998) noticed that the large varieties were concentrations of fiber 6.47% in DM (Agat) to 26.14% in DM (Rubin).

Stanek et al. (2004) reported that the white-flowering peas seeds contained less neutral detergent fibre (NDF) (18.72 vs. 20.54%).

Kotlarz et al. (2011) noted that the cropping year had a significant influence on crude fibre.

Patil et al. (2013) reported that the Potassium humate treated plants showed significant increase in fibre of wheat than control plants (untreated plant).

### **2.5.4 Fat**

Chris et al. (2005) reported that both the foliar and soil application of humic acid significantly improved oil content of mustard.

Kotlarz et al. (2011) noted that the cropping year had a significant influence on crude oil.

#### **2.5.5 Ash**

Kotlarz et al. (2011) noted that the cropping year had a significant influence on crude ash.

## MATERIAL AND METHODS

A field experiment entitled “Morpho-physiological traits and productivity in garden pea (*Pisum sativum* L.) as influenced by various methods of Potassium humate application” was conducted at the Experimental area, Department of Plant Physiology, JNKVV, Jabalpur ( M.P.) during Rabi season of 2014-15. The material and methodologies used in the conduct of this experiment have been briefly described as follows.

### 3.1 Details of the Experimental Material

#### Climate

Jabalpur is situated at 23' 90" N latitude and 79' 58" E longitude at an altitude of 411.78 meter above the mean sea level. It falls under subtropical climatic conditions, which is characterized by the features of hot dry summers and cool dry winters. The 10-years mean annual rainfall of the area is 1284 mm and nearly 90% of the total annual rainfall is mainly received during the period between ends of June to end of September. The rainfall is often erratic and ill-distributed along with an occasional long dry spells or frequent heavy rainy days during rainy season. There is possibility of occasional and little rainfall during rest period of the year. The maximum and minimum temperature ranges between 24 °C to 45 °C and 4 °C to 32 °C, respectively within a year. In some of the years, maximum temperature reaches as high as 45 °C in the month of May or June, while minimum temperature falls 2 °C down to a limit of 4 °C during end of December or January months. The relative humidity varies from season to season. It ranges between 80 to 90 % during rainy season, which reduces as 60 to 70 and 30 to 40 % during winter and summer seasons, respectively.

### 3.2 Weather Conditions

The prevailing weather parameters viz., temperature, rainfall, relative humidity, sunshine hours and wind velocity etc. of Jabalpur during entire crop growth season were recorded from the Meteorological Observatory, College of Agricultural Engineering, JNKVV, Jabalpur. These data are presented in Table 1 and also illustrated graphically through the (Table 1, Fig 1).

**Table 1. Meteorological data during the rabi season 2014-15**

Month	SMW	Tem. max.	Tem. min.	Sun Shine hrs.	Rainfall (mm)	RH Mor.	RH Eve.	Wind Speed km/hr.	No. of Rainy days
Nov.	45	31.0	13.9	08.2	0000	87	29	2.6	00
	46	30.4	14.4	06.0	0000	83	26	2.5	00
	47	28.4	08.9	08.6	0000	82	20	1.8	00
Dec.	48	29.2	10.2	08.6	0000	85	24	2.1	00
	49	26.9	08.0	08.7	0000	88	24	2.5	00
	50	25.0	11.8	06.2	004.8	89	52	2.6	01
	51	22.2	05.6	07.6	0000	86	32	2.2	00
	52	23.2	04.8	08.5	0000	87	32	2.1	00
Jan.	01	20.5	11.7	06.5	037.7	90	61	3.8	03
	02	22.1	05.3	08.5	0000	87	38	2.1	00
	03	22.2	05.3	08.3	0000	91	37	2.6	00
	04	21.6	12.1	03.7	010.2	89	75	3.3	02
	05	22.5	08.7	09.8	010.8	85	44	2.7	02
Feb.	06	24.2	10.2	07.1	014.4	88	52	4.5	01
	07	26.8	10.4	09.1	006.2	88	40	2.8	01
	08	30.6	12.0	09.7	0000	86	33	1.9	00
	09	26.7	14.5	06.8	064.8	85	54	3.2	03

It is evident from the data (Table 1, Fig. 1) that weather conditions were almost favorable for the growth and development of garden pea. The total rainfall received during the crop season was 148.9 mm, which was distributed in 13 rainy days from November to last week of February with the maximum 85.4 mm occurrence in the month of February. Minimum and maximum mean temperature ranged from 4.8 °C to 31.0 °C, respectively. The relative humidity ranged from 82 to 91 % in morning and 20 to 75 % in evening. The mean sunshine hours remained between 3.7 to 9.8 hours per day.

### 3.3 Pre sowing operations

The field was prepared by tilling the land with tractor drawn cultivator followed by two harrowing with disc harrow to develop fine tilth. The field was then finally leveled by using tractor operated leveler. After this, experiment was lay out.

### 3.4 Technical programme of work:-

**Location:** Experimental area, Department of Plant Physiology, JNKVV, Jabalpur (M.P.).

#### Details of experiment:-

Season : Rabi (2014-15)

Design : Randomized Block Design(RBD)

Treatments : 07 Viz;

- T<sub>1</sub> Only normal package of practices without application of Potassium humate (control).
- T<sub>2</sub> Soil application of Potassium humate 4.5@ 5 liter/ acre before the basal dose of manure/ fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after one month of first application.
- T<sub>3</sub> Soil application of Potassium humate 4.5@ 5 liter/ acre before the basal dose of manure/ fertilizer + Second soil application 5 liter/ with 150 liter of water one month of the first application.
- T<sub>4</sub> Soil application of Potassium humate 4.5@ 5 liter / acre before the basal dose of manure/ fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after 45 days of first application.
- T<sub>5</sub> Soil application of Potassium humate 4.5@ 5 liter/ acre before the basal dose of manure/ fertilizer + soil application of Potassium humate 4.5@ 5 liter in 150 liter of water + after 30 days of first application + foliar spray of Potassium humate 4.5@ 3 liter in 150 liter of water after 45 days of second application.
- T<sub>6</sub> Soil application of Potassium humate 4.5@ 5 liter/ acre before the basal dose of manure/ fertilizer + foliar spray of Potassium humate @ 5 liter in 250 liter of water immediately after first picking.
- T<sub>7</sub> Soil application of Potassium humate 4.5@ 5 liter/ acre before the basal dose of manure/ fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after 15 days of first picking.

Replications	: 03
Distance between rows	: 30 cm.
Distance between plot to plot	: 0.5 m.
Distance between replication	: 1.0 m.
Plot size (Gross plot)	: 3.9 m. x 4.0 m.
Net plot size	: 2.7 m. x 3.0 m.
Total experimental area	: 14.0 m x 30.3 m (424.2 m <sup>2</sup> )
Number of rows / plot	: 13
Row length	: 3.0 m.
Crop	: Garden pea
Seed rate	: 100 kg ha <sup>-1</sup>
Fertilizer doses	: 30 kg N, 70 kg p, 40 kg k ha <sup>-1</sup>
Date of sowing	: 08/11/2014
Date of harvesting	: 28/2/2015

#### **3.4.1 Seed treatments**

The seeds were treated with carbendazim 2.5 g kg<sup>-1</sup> seeds and rizobium leguminosarum 10 g kg<sup>-1</sup> seeds.

#### **3.4.2 Seed sowing**

The seeds were sown in the Field by hand dibbling keeping the row to row distance of 30 cm.

#### **3.4.3 Intercultural operations**

Three hand weddings were done at 25, 45 and 95 days after sowing (DAS) to keep the experimental plots weeds free.

#### **3.4.4 Irrigation management**

Irrigation was applied after sowing 1, 17, 35 and 53 (DAS).

#### **3.4.5 Fertilizer and manure application**

Nitrogen, phosphorus and potassium were applied at 30:70:40, kg ha<sup>-1</sup>, NPK respectively in each plot.

### **3.4.6 Harvesting and threshing**

The final harvesting was carried out on February to March and the plants were sun dried, threshed and analyzed for various yield components and yield.

### **3.5 Observations**

The observations were subdivided into following groups and recorded during the Rabi season.

#### **3.5.1 Phenophases:**

**3.5.1.1** Days to seedling emergence

**3.5.1.2** Days to 2 to 4 leaf stages

**3.5.1.3** Days to tendril formation

**3.5.1.4** Days to 1<sup>st</sup> flower initiation

**3.5.1.5** Days to 50 % flowering

**3.5.1.6** Days to pod initiation

**3.5.1.7** Days to seed formation

**3.5.1.8** Days to 1<sup>st</sup> picking

**3.5.1.9** Days to Physiological maturity

**3.5.1.10** Days to physical maturity

#### **3.5.2. Physiological parameters:**

##### **3.5.2.1 Dry matter production**

Estimation of leaf area and dry matter production and partitioning in leaves, main stem, tendrils, pods etc. at 20 days intervals till maturity.

##### **3.5.2.2 Growth parameters**

**3.5.2.2.1** LAI (Leaf Area Index) (Gardner et al., 1985)

**3.5.2.2.2** LAD (Leaf Area Duration cm<sup>2</sup>. days) (Watson, 1952)

**3.5.2.2.3** CGR (Crop Growth Rate g/cm<sup>2</sup>/day) (Watson, 1952)

**3.5.2.2.4** RGR (Relative Growth Rate g g<sup>-1</sup> day<sup>-1</sup>) (Watson, 1952)

**3.5.2.2.5** SLA (Specific Leaf Area  $\text{cm}^2 \text{g}^{-1}$ ) (Gardner et al., 1985)

**3.5.2.2.6** SLW (Specific leaf weight  $\text{g cm}^{-2}$ ) (Gardner et al., 1985)

**3.5.2.2.7** BMD (Biomass duration  $\text{g days}$ )

### **3.5.3 Other physiological traits**

**3.5.3.1** Chlorophyll content index: (Chlorophyll meter)

**3.5.3.2** Quantum efficiency : (IRGA)

**3.5.3.3** Carboxylation efficiency : ( $\mu \text{mol m}^{-2} \text{Sec}^{-1}$ ) ( $\mu \text{mol mol}^{-1}$ )<sup>-1</sup> IRGA

**3.5.3.4** Water use efficiency : ( $\mu \text{mol mmol}^{-1}$ )

**3.5.3.5** Mesophyll efficiency :  $\mu \text{mol mol}^{-1} (\text{mol m}^{-2} \text{Sec}^{-1})^{-1}$ , IRGA

**3.5.3.6** Canopy temperature :  $^{\circ}\text{c}$  (IRGA)

**3.5.3.7** Photosynthesis Active Radiation absorption: ( $\mu \text{mol m}^{-2} \text{Sec}^{-1}$ ), IRGA

**3.5.3.8** Net Photosynthesis Rate- : ( $\mu \text{mol m}^{-2} \text{Sec}^{-1}$ ), IRGA

**3.5.3.9** Stomatal conductance : ( $\text{mol m}^{-2} \text{Sec}^{-1}$ ), IRGA

**3.5.3.10** Transpiration Rate- : ( $\text{m mol m}^{-2} \text{Sec}^{-1}$ ), IRGA

### **3.6 Yield and yield components**

**3.6.1** Plant height (cm) **3.6.8** Pod length (cm.)

**3.6.2** Number of nodes  $\text{plant}^{-1}$  **3.6.9** Pod width (mm.)

**3.6.3** Number of pods  $\text{plant}^{-1}$  **3.6.10** Pod girth (mm.)

**3.6.4** Number of filled pods  $\text{plant}^{-1}$  **3.6.11** Green pod yield ( $\text{g plant}^{-1}$ )

**3.6.5** Number of empty pods  $\text{plant}^{-1}$  **3.6.12** Seed yield ( $\text{g plant}^{-1} \text{kg ha.}^{-1}$ )

**3.6.6** Number of seeds  $\text{pod}^{-1}$  **3.6.13** Biological yield ( $\text{g plant}^{-1} \text{kg ha.}^{-1}$ )

**3.6.7** 100 seeds weight (g) **3.6.14** Harvest Index (%)

### **3.7 Proximate analysis**

**3.7.1** Protein (%) (AOAC, 1980)

**3.7.2** Carbohydrate (%) (Sadasivam and Manickam, 1992)

**3.7.3** Fiber (%) (Sadasivam and Manickam, 1992)

### 3.7.4 Fat (%)

### 3.7.5 Ash (%)

The details are given as follows:

#### 3.5.1 Phenophases

The phenological observations were noted from three selected and tagged plants throughout the growth period through daily visual observations.

The phenophases Viz; Days to seedling emergence, days to 2 to 4 leaf stages, days to tendrils formation, days to 1<sup>st</sup> flower initiation, days to 50 % flowering, days to pod initiation, days to seed formation, days to 1<sup>st</sup> picking, days to physiological maturity and days to physical maturity were recorded in Garden pea variety Arkel.

#### 3.5.2 Physiological parameters:

##### 3.5.2.1 Sampling for DM production and growth analysis

The sampling for growth analysis and biomass partitioning was done at fixed intervals of 20 days after sowing (DAS) onwards till maturity from five randomly selected plants from each treatments and replications. Biochemical estimations were carried out at maturity stage.

##### Leaf area (cm<sup>2</sup>)

The leaf area was recorded by using Laser area meter (Model LI-300) at 20, 40, 60, 80, and 100 days after sowing.

##### 3.5.2.2 Growth parameters.

###### 3.5.2.2.1 Leaf area index (LAI)

LAI expresses the ratio of leaf surface (One side only) to the ground area occupied by the plant or a crop stand worked out as per specifications of (Gardner et al. 1985).

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}} \quad \text{LAI} = \frac{(LA_2 + LA_1)}{2/p}$$

Where the LA<sub>1</sub> and LA<sub>2</sub> represents the leaf area during the two consecutive intervals and 'P' ground area.

### 3.5.2.2.2 Leaf area duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. It reflects the extent of seasonal integral of light interaction and correlated with yield. LAD was computed as follows: (Watson, 1952).

$$\text{LAD} = \frac{(\text{LA}_2 + \text{LA}_1)}{2} \times (t_2 - t_1) \text{ (cm}^2 \text{ .days)}$$

Where the  $\text{LA}_1$  and  $\text{LA}_2$  represents the leaf area at two successive time intervals ( $t_1$  and  $t_2$ ).

### 3.5.2.2.3 Crop growth rate (CGR)

The daily increment in plant biomass is termed as crop growth rate (Watson, 1952) or productivity rate (Leith, 1955) or rate of dry matter production. It was determined as per the following formula suggested by (Watson, 1952).

$$\text{CGR} = \frac{W_2 - W_1}{p (t_2 - t_1)} \text{ (g cm}^{-2} \text{ ground area/day)}$$

Where,

$p$  = ground area ( $\text{cm}^2$ )

$W_1$  = dry weight per unit area at  $t_1$

$W_2$  = dry weight per unit area at  $t_2$

$t_1$  = first sampling and

$t_2$  = second sampling

### 3.5.2.2.4 Relative growth rate (RGR)

The Relative growth rate expresses the dry weight increase in time interval in relation to initial weight. In practical situations, the mean relative growth rate is calculated from measurements at  $t_1$  and  $t_2$ . It was calculated as per formula given by (Watson, 1952).

$$\text{RGR} = \frac{\text{Ln } W_2 - \text{Ln } W_1}{t_2 - t_1} \text{ (g g}^{-1} \text{ day}^{-1}\text{)}$$

Ln represents natural log.

### 3.5.2.2.5 Specific leaf area (SLA)

The specific leaf area expresses the ratio between the leaf area (LA) and leaf dry weight (LW) (Gardner et al. 1985).

$$SLA = \frac{(LA_2/LW_2 + LA_1/LW_1)}{2} \text{ (cm}^2 \text{ g}^{-1}\text{)}$$

### 3.5.2.2.6 Specific leaf weight (SLW)

The specific leaf weight expresses the ratio between the leaf dry weight (LW) and leaf area (LA) (Gardner et al. 1985).

$$SLW = \frac{(WL_1/LA_1 + WL_2/LA_2)}{2} \text{ (g cm}^{-2}\text{)}$$

### 3.5.2.2.7 Biomass duration (BMD)

$$BMD = \frac{W_2 - W_1}{\ln W_2 - \ln W_1} (t_2 - t_1) \text{ (g.day)}$$

## 3.5.3 Other physiological traits

### 3.5.3.1 Determination of chlorophyll content index

Chlorophyll content which is expressed as grams of chlorophyll per unit granted area (Nishimura, 1954; Okubo et al., 1958) was determined in the 4th leaf of five weeks old plant using a non-destructive method that uses an optical instrument called chlorophyll meter (Model: CCM 200 Made in USA).

### 3.5.3.2 Quantum efficiency:

The quantum efficiency was determined as per formula given by (Pandey et al., 2001) as follows:

$$Q.E. = \frac{P_n}{Q}$$

Where, the  $P_n$  refers to the net photosynthesis and  $Q$  refers to the PAR absorption.

Gas exchange rates and other physiological traits were measured on intact leaves using a LICOR Infra Red Gas Analyzer IRGA, LI-5400 XT (LICOR Inc, Lincoln, NE, USA), fitted with a leaf chamber mounted with a

source of light. Fully expanded youngest fourth leaves were used for photosynthesis measurements.

### **3.5.3.3 Carboxylation efficiency ( $\sim \text{mol m}^{-2} \text{s}^{-1} (\sim \text{mol mol}^{-1})^{-1}$ )**

The carboxylation efficiency was worked out as per specifications given by (Kannan and Vankataraman, 2010) as follows:

$$\text{C.E.} = \frac{P_n}{C_i}$$

Where, the  $P_n$  refers to the net photosynthesis and  $C_i$  refers to the intercellular  $\text{CO}_2$  concentration.

### **3.5.3.4 Water Use Efficiency ( $\sim \text{mol}/\text{mmol}$ )**

The water use efficiency was determined as per method given by (Kannan and Vankataraman, 2010) as follows:

$$\text{WUE} = \frac{P_n}{E}$$

Where,  $P_n$  represents the net photosynthesis and  $E$  refers to the transpiration rate.

### **3.5.3.5 Mesophyll efficiency ( $\sim \text{mol mol}^{-1} (\text{mol m}^{-2} \text{s}^{-1})^{-1}$ )**

The mesophyll efficiency was determined as per method given by (Kannan and Vankataraman, 2010) as follows:

$$\text{ME} = \frac{C_i}{\text{Cond}}$$

Where, the  $C_i$  refers to the intercellular  $\text{CO}_2$  concentration and  $\text{cond}$  refers to the stomatal conductance.

The following observations were also recorded by using IRGA (Infrared gas analyser)

**3.5.3.6** Canopy temperature ( $^{\circ}\text{C}$ ).

**3.5.3.7** Photosynthesis Active Radiation absorption ( $\mu \text{mol m}^{-2} \text{Sec}^{-1}$ ).

**3.5.3.8** Net Photosynthesis rate ( $\mu \text{mol m}^{-2} \text{Sec}^{-1}$ ).

**3.5.3.9** Stomatal conductance ( $\text{m mol}/\text{m}^2/\text{sec}$ ).

**3.5.3.10** Transpiration rate ( $\text{m mol}/\text{m}^2/\text{sec}$ ).

## **Post-harvest Observations**

### **3.6 Yield and yield attributing traits**

#### **3.6.1 Plant height (cm)**

The plant height was recorded by tagging five plants at maturity.

#### **3.6.2 Number of nodes plant<sup>-1</sup>**

The number of nodes plant<sup>-1</sup> was recorded by tagging five plants at maturity.

#### **3.6.3 Number of pods plant<sup>-1</sup>**

The number of pods plant<sup>-1</sup> was recorded from five tagged plants at maturity.

#### **3.7.4 Number of filled pods plant<sup>-1</sup>**

The number of filled pods plant<sup>-1</sup> was recorded from five tagged plants at maturity.

#### **3.6.5 Number of empty pods plant<sup>-1</sup>**

The number of empty pods plant<sup>-1</sup> was recorded from five tagged plants at maturity.

#### **3.6.5 Number of seeds pod<sup>-1</sup>**

The number of seeds pod<sup>-1</sup> was recorded from five tagged plants at maturity.

#### **3.6.7 100 seeds weight (g)**

100 seeds were taken from the produce of each plot and their weight was recorded by electronic balance.

#### **3.6.8 Pod length (cm.)**

The pod length was recorded by using the scale from randomly 30 selected pods from each treatment.

#### **3.6.9 Pod width (mm.)**

The pod width was recorded by using the digital vernier calipers from top, middle and bottom of pod and average was recorded as the pod width.

### **3.6.10 Pod girth (mm.)**

The pod girth was recorded by using the digital vernier calipers from top, middle and bottom of pod and average was recorded as the pod girth.

### **3.6.11 Green pod yield (g plant<sup>-1</sup>)**

The green pod yields g plant<sup>-1</sup> was recorded at different times of picking as soon as pods attain the ripening.

### **3.6.12 Seed yield (g plant<sup>-1</sup>,<sup>-1</sup> kg ha.<sup>-1</sup>)**

The seed yields g plant<sup>-1</sup> and kg ha.<sup>-1</sup> were recorded after threshing, cleaning and drying the seeds. It is also known as economical yield.

### **3.6.13 Biological yield (g plant<sup>-1</sup>,<sup>-1</sup> kg ha.<sup>-1</sup>)**

Biological yield is the total yield of crop including economic yield and the Stover yield. The biological yield g plant<sup>-1</sup> and kg ha.<sup>-1</sup> was recorded after harvesting.

### **3.6.14 Harvest Index (%)**

Harvest index is the ratio of economic yield to the total biological yield expressed in percentage. It represents the efficiency of photosynthates translocation to economic parts (Synder and Carlson, 1984).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

While calculating the biological yield only the above ground parts were taken into consideration.

## **3.7 Proximate analysis**

The garden pea were analyzed for the biochemical constituents as follows:

### **3.7.1 Estimation of protein and nitrogen in seed**

The nitrogen content was estimated by micro kjeldhal method (A.O.A.C., 1965) as given under by (Gopalan et al., 1985): 0.1 gm of sample was digested with concentrated sulphuric acid (10 ml) in 9 digestion of (CuSO<sub>4</sub>, 5 H<sub>2</sub>O and 0.34 g solution selenate). After digestion for about 3 hours till liquid becomes colourless, the digestion tube was allowed to cool and the

contents carefully diluted to 100 ml with distilled water. The solution is then transferred quantitatively to a distillation apparatus, 15 ml of 40% of sodium hydroxide was added and the liberating ammonia was collected in a flask containing 10 ml of 2 percent boric acid with two drops of mixed indicator (Bromocrysol green + methyl red). Distillation was continued for 5 minute appearance of green colour to ensure the complete evaluation of ammonia. After distillation solution was titrated with 0.1N H<sub>2</sub>SO<sub>4</sub>.

Nitrogen and protein percent was calculated by the following formula:

$$\text{Nitrogen} = \frac{14 \times \text{Normality of H}_2\text{SO}_4 \times (\text{TV-TB}) \times \text{Vol. of H}_2\text{SO}_4 \times 100}{\text{weight of sample} \times 100}$$

Protein percent in the sample was estimated multiplying nitrogen percent of sample by factor 5.25.

$$\text{Protein (\%)} = \text{Nitrogen \%} \times 5.25$$

### **3.7.2 Estimation of total carbohydrate percentage**

Total carbohydrates in the sample was estimated by the hydrolysis method as described in (AOAC, 1984)

#### **Reagents:**

1. 5 % phenol: Dissolve 50 g of redistilled (reagent grade) phenol in water and dilute to one liter.
2. 95 % sulphuric acid (reagent grade).
3. Standard glucose: stock – 100 mg in 1(x) ml of water
4. Working Standard 10ml of stock diluted to 100ml with distilled water.

#### **Procedure:**

1. Weigh 100mg of the sample into a boiling tube.
2. Hydrolyze by keeping it in a boiling water bath for 3 hr. with 5 ml of 2.5 N HCL and cool to room temperature.
3. Neutralize it with solid sodium carbonate until the effervescence ceases.
4. Make up the volume to 100ml and centrifuge.

5. Pipette out 0.2, 0.5, 0.8 and 1 ml of working standard into a series of test tubes.
6. Pipette out 0.1 and 0.2 ml of the sample solution in two separate test tubes. Make up the volume in each tube to 1ml with water.
7. Set a blank with 1 ml of water.
8. Add 1 ml of phenol solution to each tube.
9. Add 5 ml of 95% sulphuric acid to each tube and shake well.
10. After 10 min shakes the contents in the tubes and place in a water bath at 25-300 C for 20 min.
11. Read the colour at 490 nm.
12. Calculate the amount of total carbohydrate present in the sample solution using the standard graph.

Calculate

$$\text{Total carbohydrate in the sample} = \frac{\text{sugar value from graph } (\mu\text{g})}{\text{Aliquot sample used (0.1 or 0.2)}} \times \frac{\text{Total volume of extract (100 ml)}}{\text{Weight of sample (100mg)}} \times 100$$

### 3.7.3 Total crude fibre

#### Materials

1. Sulphuric acid solution: 12.5 ml of conc. sulphuric acid was diluted to 1 liter distilled water.
2. Sodium hydroxide solution: 12.5 g of sodium hydroxide was dissolved in 1 liter distilled water.

#### Procedure

1 g of defatted seed sample obtained from estimation of fat % was weighed accurately and noted (W). The weighed samples were then transferred to oven dried crucibles. The crucibles were then placed in to metal adapters of the fibre plus hot extraction unit and proper sealing of crucibles against the adapter rubber was ensured. 150 ml of 1.25 % H<sub>2</sub>SO<sub>4</sub> was then poured into the extractors from the top. The instrument was switched on and

the temperature was set to 40-52 °C and the samples were boiled for 30 minutes in the acid. After boiling, the acid was drained out and the samples were washed twice or thrice with distilled water. After washing, 150 ml of 1.25% NaOH was poured into the extractors. The instrument was switched on again at a temperature of 40-52 °C and against boiled for another 40 minutes. When the process is over the alkali was drained out and the sample was again washed with distilled water. The crucibles were then taken out and kept in hot air oven unit the crucibles are free from moisture. The crucibles were cooled down using a desiccator and the crucibles were weighed ( $W_1$ ). The crucibles were then finally placed in a muffle furnace for ashing at 550 °C. The hot crucibles were cooled after ashing and finally the crucible were weighed ( $W_2$ ).

$$\% \text{ Crude fibre} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

#### **3.7.4 Determination of fat percentage**

The fat content in the sample was estimated by PALICAN EQUIPMENT SOCS PLUS based on principle of Soxhlet's extraction method as described in (AOAC, 1980). The extract method used for this purpose is given below:

##### **Procedure**

2 g of sample was weighed accurately into a thimble and plugged with fat free cotton. The extraction flask (A). Fat content was determined by extracting the sample with solvent, petroleum ether A.R. grade 50-80<sup>0</sup> fraction, for 5 hours by Soxhlet's extraction procedure. After extraction excess of ether is evaporated until no colour of ether remained. Cooled at room temperature and weighed the flask (B). The percent of fat was calculated by using following formula.

$$\text{Fat (\% in ground sample)} = \frac{\text{Wt. of flask (B)} - \text{Wt. of flask (A)}}{\text{Wt. of sample}} \times 100$$

### 3.7.5 Total ash

The ash content in the seed sample was estimated according to (AOAC, 1980). The details procedure used is given below:

#### Procedure

Four gram of sample was weighed accurately into a weighed. Proclaim crucible (which had preciously been heated to about 500 °C and cooled). The crucible was heated first over a low lame till all material was completely charged, followed by heating in a muffle furnace for about 500 °C it was then cooled in a desiccator and weighed. The ensure completion of ashing. The crucible was again heated in the muffle furnace for 1-2 hours then cooled and weighed. This was repeated till two consecutive weights were same and then ash was almost white or grayish white in colour.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

### 3.8 Statistical analysis

Analysis of observations taken on different variables was carried out to know the degree of variation among all the treatments. The pooled data was statistically analysed through randomized block design (Fisher, 1967). The results obtained through analysis of variance is given in appendix and the skeleton of analysis of variance (Table 2.) given below :

S. No.	Source of variance	Degree of freedom (df)	Sum of square (SS)	Mean sum of square (MSS)	Calculated F. value	Table value (5%)
1.	Replications	(r-1) = 2				
2.	Treatments	(t-1) = 6				
3.	Error	(r-1)(t-1) = 12				
	Total	(rt-1) = 20				

$$SEm_{\pm} = \sqrt{EMS/r}$$

$$SEd_{\pm} = \sqrt{2EMS/r}$$

$$CD = SEd_{\pm} \times t \text{ at } 5\%$$

where,

$r$  = No. of replications

EMS = Error mean square

SE $m_{\pm}$  = Standard error of treatment mean

SE $d_{\pm}$  = Standard error of difference to two treatment mean

CD = Critical difference to two treatments mean

## RESULTS

The present investigations entitled “**Morpho-physiological traits and productivity in gardenpea (*Pisum sativum* L.) as influenced by various methods of Potassium humate - 4.5 application**” revealed various valuable findings.

The results of investigations are presented under the following subheads:

### **4.1 Phenophases:**

4.1.1 Days to seedling emergence

4.1.2 Days to 2 to 4 leaf stages

4.1.3 Days to tendril formation

4.1.4 Days to 1<sup>st</sup> flower initiation

4.1.5 Days to 50 % flowering

4.1.6 Days to pod initiation

4.1.7 Days to seed formation

4.1.8 Days to 1<sup>st</sup> picking

4.1.9 Days to Physiological maturity

4.1.10 Days to physical maturity

### **4.2 Physiological parameters:**

#### **4.2.1 Dry matter production**

4.2.1.1 Leaves dry weight plant<sup>-1</sup>

4.2.1.2 Stem dry weight plant<sup>-1</sup>

4.2.1.3 Tendril dry weight plant<sup>-1</sup>

4.2.1.4 Pods dry weight plant<sup>-1</sup>

4.2.1.5 Total dry weight plant<sup>-1</sup>

## **4.2.2 Growth parameters**

4.2.2.1 LAI (Leaf Area Index)

4.2.2.2 LAD (Leaf Area Duration)

4.2.2.3 CGR (Crop Growth Rate)

4.2.2.4 RGR (Relative Growth

4.2.2.5 SLA (Specific Leaf Area)

4.2.2.6 SLW (Specific leaf weight)

4.2.2.7 BMD (Biomass duration)

## **4.3 Other physiological traits**

4.3.1 Chlorophyll content index

4.3.2 Quantum efficiency

4.3.3 Carboxylation efficiency

4.3.4 Water use efficiency

4.3.5 Mesophyll efficiency

4.3.6 Canopy temperature

4.3.7 Photosynthesis Active Radiation absorption

4.3.8 Net Photosynthesis Rate

4.3.9 Stomatal conductance

4.3.10 Transpiration Rate

## **4.4 Yield and yield components**

4.4.1 Plant height (cm)

4.4.2 Number of nodes plant<sup>-1</sup>

4.4.3 Number of pods plant<sup>-1</sup>

4.4.4 Number of filled pods plant<sup>-1</sup>

4.4.5 Number of empty pods plant<sup>-1</sup>

4.4.6 Number of seeds pod<sup>-1</sup>

- 4.4.7 100 seeds weight (g)
- 4.4.8 Pod length (cm.)
- 4.4.9 Pod width (mm.)
- 4.4.10 Pod girth (mm.)
- 4.4.11 Green pod yield (g plant<sup>-1</sup>)
- 4.4.12 Seed yield (g plant,<sup>-1</sup> kg ha.<sup>-1</sup>)
- 4.4.13 Biological yield (g plant,<sup>-1</sup> kg ha.<sup>-1</sup>)
- 4.4.14 Harvest Index (%)

#### **4.5 Proximate analysis**

- 4.5.1 Protein (%)
- 4.5.2 Carbohydrate (%)
- 4.5.3 Fiber (%)
- 4.5.4 Fat (%)
- 4.5.5 Ash (%)

#### **4.1 Phenophases**

The results indicated (Table-2, Fig.-3) that almost all phenophases varied highly significantly (at 1%) among treatments. However, 2 to 4 leaf stage indicated significant difference only at 5% level and remaining phenophases non significant variation among treatments.

##### **4.1.1 Days to seedling emergence and days to tendril formation**

The results indicated that days to seedling emergence in treatments T<sub>4</sub> (5.00) and T<sub>5</sub> (4.00) and days to tendril formation in T<sub>3</sub> (16.00) and T<sub>7</sub> (15.67) were found to be associated with the highest and lowest values for these phenophases.

##### **4.1.2 Days to 2 to 4 leaf stage**

The treatments T<sub>1</sub> (12.00) and T<sub>4</sub> (11.00) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>7</sub> (10.00) registered the minimum time to achieve stage.

**Table 2: Various phenophases of garden pea under various treatments during crop growth period**

<b>Treatments</b>	<b>Days to seedling emergence</b>	<b>Days to 2 to 4 leaf stage</b>	<b>Days to tendrils formation</b>	<b>Days to 1<sup>st</sup> flower initiation</b>	<b>Days to 50 % flowering</b>	<b>Days to pod initiation</b>	<b>Days to seed formation</b>	<b>Days to 1<sup>st</sup> picking</b>	<b>Days to Physiological maturity</b>	<b>Days to physical maturity</b>
T <sub>1</sub>	4.33	12.00	15.67	35.67	41.67	43.33	50.67	75.33	105.33	111.33
T <sub>2</sub>	4.67	10.67	15.67	34.67	40.33	41.67	50.33	76.33	105.67	111.33
T <sub>3</sub>	4.67	10.67	16.00	35.33	40.33	41.67	50.00	78.33	105.67	111.33
T <sub>4</sub>	5.00	11.00	16.00	35.00	40.33	42.00	49.67	79.33	106.00	111.33
T <sub>5</sub>	4.00	10.33	15.67	34.67	39.33	41.33	49.33	74.67	103.67	109.33
T <sub>6</sub>	4.33	10.00	15.67	33.67	38.33	40.00	47.00	70.00	100.67	108.00
T <sub>7</sub>	4.67	10.00	15.67	33.00	38.33	40.33	47.00	68.00	100.67	106.33
<b>SEm ±</b>	0.3	0.395	0.552	0.36	0.35	0.39	0.747	1.007	0.733	0.707
<b>CD 5%</b>	-	1.217	-	1.12	1.06	1.21	2.302	3.102	2.258	2.179

#### **4.1.3 Days to 1<sup>st</sup> flower initiation**

The results indicated that the treatment T<sub>1</sub> (35.67) took more time to acquire this stage which was at par with T<sub>3</sub> (35.33), T<sub>4</sub> (35.00) and T<sub>2</sub>, T<sub>5</sub> (34.67). Treatment T<sub>7</sub> (33.00) recorded the minimum time to attain this stage.

#### **4.1.4 Days to 50 % flowering**

The treatment T<sub>1</sub> (41.67) indicated significant higher days to attain 50 % flowering over rest of the treatments. T<sub>7</sub> (38.33) took the minimum time to reach this stage.

#### **4.1.5 Days to pod initiation**

The treatment T<sub>1</sub> (43.33) recorded significant more days for pod initiation over rest of the treatments. Treatments T<sub>4</sub> (42.00), T<sub>2</sub>, T<sub>3</sub> (41.67) and T<sub>5</sub> (41.33) did not differ significantly among them. T<sub>6</sub> (40.00) recorded the minimum time for this stage.

#### **4.1.6 Days to seed formation**

The results indicated that the more days to seed formation was recorded in treatment T<sub>1</sub> (50.67) which was at par with T<sub>2</sub> (50.33), T<sub>3</sub> (50.00), T<sub>4</sub> (49.67) and T<sub>5</sub> (49.33). Treatment T<sub>7</sub> (47.00) recorded the minimum.

#### **4.1.7 Days to 1<sup>st</sup> picking**

The results showed that the treatments T<sub>4</sub> (79.33), T<sub>3</sub> (78.33) and T<sub>2</sub> (76.33) recorded the higher magnitudes for days to 1<sup>st</sup> picking though they did not differ significantly among them. Treatment T<sub>7</sub> (68.00) recorded lowest value time to acquire this phase.

#### **4.1.8 Days to Physiological maturity**

The results indicated that the treatment T<sub>4</sub> (106.00) required more number days to attain physiological maturity at par with T<sub>2</sub> (105.67), T<sub>3</sub> (105.67) and T<sub>1</sub> (105.33). Treatment T<sub>7</sub> (100.67) recorded the minimum time for the same.

#### **4.1.9 Days to physical maturity**

The results indicated that the T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> (111.33) attained the physical maturity at the longest period. Treatment T<sub>7</sub> (106.33) recorded the minimum number of days to exhibit this phase.

Thus the investigations revealed that the treatment T<sub>2</sub> (76.66 days) was found to be associated with the longest reproductive period, whereas T<sub>5</sub> (74.66 days) recorded a quite less time for this period. On the other hand T<sub>4</sub> (61.66 days) had the longest seed filling period, where T<sub>5</sub> (60.00 days) recorded the minimum time for seed filling. Treatment T<sub>1</sub> (37.34 days) had the longest vegetative phase and T<sub>7</sub> (33.66 days) shortest.

## 4.2 Physiological traits

### 4.2.1 Dry matter production and partitioning

#### 4.2.1.1 Dry matter production in leaves (g plant<sup>-1</sup>)

The treatments varied significantly (at 5%) with respect to DM accumulation in leaves at 60 DAS and highly significantly (at 1%) during rest of the growth period (Table 3, Fig. 4).

#### At 20 DAS

The results indicated that the higher leaves dry weight was recorded in treatment T<sub>3</sub> (0.18) which was at par with T<sub>2</sub>, T<sub>7</sub> (0.17) and T<sub>6</sub> (0.16). Treatment T<sub>5</sub> (0.15) recorded the minimum.

**Table 3: DM accumulation (g plant<sup>-1</sup>) in leaves during successive growth period in various treatments**

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.15	0.82	1.97	2.34	2.32	2.20	1.63
T <sub>2</sub>	0.17	0.79	2.08	4.34	2.91	2.36	2.11
T <sub>3</sub>	0.18	0.92	2.79	2.82	2.75	2.72	2.03
T <sub>4</sub>	0.15	1.19	2.06	3.51	2.60	2.59	2.02
T <sub>5</sub>	0.15	0.85	2.10	2.94	2.88	2.83	1.96
T <sub>6</sub>	0.16	0.88	2.83	3.59	3.00	2.62	2.18
T <sub>7</sub>	0.17	1.00	2.21	2.76	2.76	2.50	1.90
SEm ±	0.01	0.06	0.17	0.30	0.08	0.08	0.12
CD 5%	0.02	0.17	0.51	0.92	0.25	0.25	0.35

\*DAS – Days after sowing

### **At 40 DAS**

The treatment T<sub>4</sub> (1.19) significantly superseded rest of the treatments for leaves dry weight at 40 DAS. Treatment T<sub>2</sub> (0.79) was found to be associated with the lowest magnitude for this trait.

### **At 60 DAS**

The treatments T<sub>6</sub> (2.83) and T<sub>3</sub> (2.79) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (1.97) registered the minimum.

### **At 80 DAS**

The study showed that the treatment T<sub>2</sub> (4.34) possessed the maximum dry weight in leaves though was at par with T<sub>6</sub> (3.59) and T<sub>4</sub> (3.51). Treatment T<sub>1</sub> (2.34) recorded the minimum leaves dry weight.

### **At 100 DAS**

The study showed that the treatment T<sub>6</sub> (3.0) possessed the maximum leaf dry weight though was at par with T<sub>2</sub> (2.91) and T<sub>5</sub> (2.88). Treatment T<sub>1</sub> (2.32) recorded the minimum.

### **At harvest**

The results indicated that the higher leaves dry weight was recorded in treatment T<sub>5</sub> (2.83) which was at par with T<sub>3</sub> (2.72), T<sub>6</sub> (2.62) and T<sub>4</sub> (2.59). Treatment T<sub>1</sub> (2.20) recorded the minimum.

Thus it can be concluded from the investigations that leaves dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined. Treatments T<sub>6</sub> (2.18 g) and T<sub>2</sub> (2.11 g) were associated with an average higher DM production in leaves.

#### **4.2.1.2 DM accumulation in main stem (g plant<sup>-1</sup>)**

The treatments varied significantly (at 5%) with respect to DM accumulation in main stem and highly significantly (at 1%) during most of the growth span except 20 DAS, The treatments did not vary significantly (Table 4, Fig. 4).

### At 20 DAS

The results indicated that at 20 days treatments T<sub>7</sub> (0.07) and T<sub>6</sub> (0.05) were found to be associated with the highest and lowest values for this trait.

**Table 4: DM accumulation (g plant<sup>-1</sup>) in main stem in garden pea during successive growth period in various treatments**

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.05	0.57	2.49	3.43	3.25	3.83	2.27
T <sub>2</sub>	0.06	0.65	2.85	5.33	3.70	3.62	2.70
T <sub>3</sub>	0.05	0.70	3.27	4.30	3.42	3.42	2.53
T <sub>4</sub>	0.05	0.99	2.55	4.45	3.45	4.18	2.61
T <sub>5</sub>	0.05	0.76	2.63	4.39	4.05	4.41	2.71
T <sub>6</sub>	0.05	0.68	3.37	4.05	4.04	3.85	2.67
T <sub>7</sub>	0.07	0.81	2.54	4.32	4.18	3.37	2.55
SEm ±	0.01	0.05	0.13	0.20	0.18	0.14	0.12
CD 5%	-	0.15	0.40	0.63	0.56	0.43	0.43

\*DAS – Days after sowing

### At 40 DAS

The treatment T<sub>4</sub> (0.99) significantly superseded rest of the treatments for stem dry weight at 40 DAS. T<sub>1</sub> (0.57) was found to be associated with the lowest magnitude for this trait.

### At 60 DAS

The treatments T<sub>6</sub> (3.27) and T<sub>3</sub> (3.27) recorded the higher magnitudes for this trait though they did not differ significantly between them. T<sub>1</sub> (2.49) registered the minimum stem dry weight.

### At 80 DAS

The treatment T<sub>2</sub> (5.33) significantly superseded the rest of the treatments for stem dry weight at 80 DAS. T<sub>1</sub> (3.43) was found to be associated with the lowest magnitude for this trait.

### **At 100 DAS**

The results indicated that the higher stem dry weight was recorded in treatment T<sub>7</sub> (4.18) which was at par with T<sub>5</sub> (4.05), T<sub>6</sub> (4.04) and T<sub>2</sub> (3.70). T<sub>1</sub> (3.25) recorded the minimum.

### **At harvest**

The treatments T<sub>5</sub> (4.41) and T<sub>4</sub> (4.18) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (3.37) registered the minimum stem dry weight.

It is evident from the investigations that stem dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it had a fluctuating trend till maturity. Treatments T<sub>5</sub> (2.71 g) and T<sub>7</sub> (2.70 g) possessed an average higher stem dry weight.

#### **4.2.1.3 Dry matter production in tendrils (g plant<sup>-1</sup>) during successive growth span**

The treatments varied significantly (at 5%) with respect to DM accumulation in tendrils at 60 DAS and highly significantly (at 1%) during rest of the growth period except at 20 DAS, non significant variation was obtained (Table 5, Fig. 4).

### **At 20 DAS**

The results indicated that at 20 days treatments T<sub>7</sub> (0.0006) and T<sub>6</sub> (0.0004) were found to be associated with the highest and lowest values for this trait.

### **At 40 DAS**

The treatments T<sub>4</sub> (0.14) and T<sub>7</sub> (0.12) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (0.08) registered the minimum tendril dry weight.

### **At 60 DAS**

The results indicated that the higher tendril dry weight was recorded in treatment T<sub>3</sub> (0.34) which was at par with T<sub>4</sub> (0.33), T<sub>5</sub> (0.28) and T<sub>6</sub> (0.28). Treatment T<sub>2</sub> (0.22) recorded the minimum.

**Table 5: DM accumulation (g plant<sup>-1</sup>) in tendrils during successive growth period in various treatments**

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.0004	0.08	0.26	0.29	0.27	0.25	0.19
T <sub>2</sub>	0.0004	0.11	0.22	0.45	0.29	0.23	0.22
T <sub>3</sub>	0.0005	0.11	0.34	0.35	0.24	0.23	0.21
T <sub>4</sub>	0.0005	0.14	0.33	0.47	0.35	0.35	0.27
T <sub>5</sub>	0.0005	0.11	0.28	0.32	0.29	0.27	0.21
T <sub>6</sub>	0.0004	0.09	0.28	0.34	0.34	0.24	0.22
T <sub>7</sub>	0.0006	0.12	0.25	0.38	0.36	0.24	0.23
SEm ±	0.00005	0.0078	0.024	0.020	0.019	0.013	0.013
CD 5%	-	0.0240	0.074	0.063	0.059	0.041	0.052

\*DAS – Days after sowing

#### **At 80 DAS**

The treatments T<sub>4</sub> (0.47) and T<sub>7</sub> (0.45) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (0.29) registered the minimum tendril dry weight.

#### **At 100 DAS**

The study showed that the treatment T<sub>7</sub> (0.36) possessed the maximum dry weight of tendril though was at par with T<sub>4</sub> (0.35) and T<sub>6</sub> (0.34). Treatment T<sub>3</sub> (0.24) recorded the minimum tendril dry weight.

#### **At harvest**

The treatment T<sub>4</sub> (0.35) significantly superseded the rest of the treatments for tendril dry weight at harvest though they did not differ significantly among them. Treatment T<sub>2</sub> and T<sub>3</sub> (0.23) registered the minimum.

Thus it can be concluded from the investigations that tendril dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined. Treatments T<sub>4</sub> (0.27 g) and T<sub>7</sub> (0.23 g) were associated with an average higher DM production in tendril.

#### 4.2.1.4 DM accumulation in pods (g plant<sup>-1</sup>)

The treatments varied highly significantly (at 1%) with respect to DM accumulation in pods throughout the growth period (Table 6, Fig. 4).

##### At 60 DAS

The study showed that the treatment T<sub>7</sub> (1.43) possessed the maximum dry weight in pods though was at par with T<sub>6</sub> (1.29) and T<sub>2</sub> (1.22). Treatment T<sub>1</sub> (0.88) recorded the minimum.

##### At 80 DAS

The treatment T<sub>2</sub> (10.98) significantly superseded the rest of the treatments for pod dry weight at 80 DAS. T<sub>5</sub> (4.27) registered the minimum.

**Table 6: DM accumulation (g plant<sup>-1</sup>) in pods in garden pea at successive growth intervals**

Treatments	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.88	5.07	12.28	13.02	7.81
T <sub>2</sub>	1.22	10.98	11.27	15.96	9.85
T <sub>3</sub>	0.90	6.08	12.82	16.48	9.07
T <sub>4</sub>	1.04	5.24	16.85	18.70	10.46
T <sub>5</sub>	1.11	4.27	17.71	21.76	11.21
T <sub>6</sub>	1.29	5.76	15.52	15.94	9.63
T <sub>7</sub>	1.43	5.23	15.90	18.33	10.22
SEm ±	0.08	0.61	0.65	0.95	0.57
CD 5%	0.26	1.89	2.00	2.93	1.77

\*DAS – Days after sowing

##### At 100 DAS

The study showed that the treatment T<sub>5</sub> (17.71) possessed the maximum dry weight of pod though was at par with T<sub>4</sub> (16.85) and T<sub>7</sub> (15.9). T<sub>2</sub> (11.27) recorded the minimum.

### **At harvest**

The treatment T<sub>5</sub> (21.76) significantly superseded rest of the treatments for pod dry weight at harvest. T<sub>1</sub> (13.02) was found to be associated with the lowest magnitude for this trait.

It has been observed from the observations that the pod dry matter accumulation was found to increase with the advancement of crop growth till maturity in all treatments. Treatments T<sub>5</sub> (11.21 g) and T<sub>4</sub> (10.46 g) were associated with an average higher DM production in pods.

#### **4.2.1.5 Total dry matter production (g plant<sup>-1</sup>)**

The treatments varied highly significantly (at 1%) among them with respect to DM accumulation in garden pea throughout the crop life span (Table 7, Fig. 4).

### **At 20 DAS**

The study showed that the treatment T<sub>7</sub> (0.24) possessed the maximum total plant dry weight though was at par with T<sub>2</sub> and T<sub>3</sub> (0.23). Treatment T<sub>1</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> (0.20) recorded the minimum.

### **At 40 DAS**

The treatment T<sub>4</sub> (2.32) indicated significant higher TDM over rest of the treatments. Though treatment T<sub>7</sub> (1.92) lagged behind the former but proved significant superiority over T<sub>1</sub> (1.47) which had the minimum TDM.

### **At 60 DAS**

The treatments T<sub>6</sub> (7.77) and T<sub>3</sub> (7.29) recorded the higher magnitudes for this trait though they did not differ significantly between them. T<sub>1</sub> (5.60) exhibited the minimum.

### **At 80 DAS**

The treatment T<sub>2</sub> (21.09) significantly superseded rest of the treatments for TDM at 80 DAS. T<sub>1</sub> (11.12) was found to be associated with the lowest magnitude for this character.

**Table 7: Total dry matter accumulation (g plant<sup>-1</sup>) in garden pea at successive growth intervals in various treatments**

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.20	1.47	5.60	11.12	18.12	19.30	9.30
T <sub>2</sub>	0.23	1.55	6.36	21.09	18.16	22.17	11.59
T <sub>3</sub>	0.23	1.73	7.29	13.56	19.22	22.85	10.81
T <sub>4</sub>	0.20	2.32	5.98	13.67	23.25	25.81	11.87
T <sub>5</sub>	0.20	1.71	6.12	11.92	24.92	29.27	12.36
T <sub>6</sub>	0.20	1.65	7.77	13.74	22.90	22.65	11.48
T <sub>7</sub>	0.24	1.92	6.42	12.69	23.20	24.45	11.49
SEm ±	0.01	0.07	0.23	0.64	0.51	0.98	0.41
CD 5%	0.02	0.22	0.71	1.96	1.58	3.03	1.25

\*DAS – Days after sowing

#### **At 100 DAS**

The treatment T<sub>5</sub> (24.92) indicated significant higher TDM over rest of the treatments. Though treatment T<sub>4</sub> (23.25) lagged behind the former but proved significant superiority over the rest except T<sub>7</sub> (23.20) and T<sub>6</sub> (22.9) which were at par. Treatment T<sub>1</sub> (18.12) recorded the minimum.

#### **At harvest**

The treatment T<sub>5</sub> (29.27) indicated significant higher TDM over rest of the treatments. Though treatment T<sub>4</sub> (25.81) lagged behind the former but proved significant superiority over the rest except T<sub>7</sub> (24.45) and T<sub>3</sub> (22.86) which were at par. T<sub>1</sub> (19.30) recorded the minimum.

Thus it can be concluded from the investigations that (Table 7 Figure 4) TDM had a continuous increase with advancement of crop age till maturity in most of the treatments except in T<sub>6</sub> it was reduced at harvest. Treatments T<sub>5</sub> (12.36) and T<sub>4</sub> (11.48) had average maximum TDM production (g/plant).

## 4.2.2 Growth analytical parameters

### 4.2.2.1 Leaf area index (LAI)

Treatments varied significantly (at 5%) at 100 DAS and highly significantly (at 1%) during rest of the investigation period as shown in (Table 8, Fig. 5).

#### At 40 DAS

The treatment T<sub>7</sub> (0.98) significantly superseded rest of the treatments for LAI at 40 DAS. T<sub>1</sub> (0.54) was found to be associated with the lowest magnitude for this trait.

#### At 60 DAS

The treatment T<sub>7</sub> (2.43) significantly superseded the rest of the treatments for LAI at 60 DAS. T<sub>4</sub> (1.78) was found to be associated with the lowest value for LAI.

**Table 8: Leaf area index (LAI) in garden pea during successive growth Intervals in different treatments**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	Average
T <sub>1</sub>	0.54	2.08	4.62	4.47	2.93
T <sub>2</sub>	0.78	2.12	4.33	4.21	2.86
T <sub>3</sub>	0.60	1.99	3.89	3.13	2.41
T <sub>4</sub>	0.71	1.78	4.00	3.85	2.59
T <sub>5</sub>	0.72	1.88	3.70	3.51	2.45
T <sub>6</sub>	0.59	2.12	4.01	3.53	2.56
T <sub>7</sub>	0.98	2.43	4.15	4.12	2.92
SEm ±	0.06	0.07	0.10	0.25	0.12
CD 5%	0.18	0.21	0.32	0.78	0.37

\*DAS – Days after sowing

#### At 80 DAS

The treatments T<sub>1</sub> (4.62) and T<sub>2</sub> (4.33) recorded the higher magnitudes for this trait though they did not vary significantly between them. Treatment T<sub>5</sub> (3.70) registered the minimum LAI.

### At 100 DAS

The results indicated that the higher LAI was recorded in treatment T<sub>1</sub> (4.47) which was at par with T<sub>2</sub> (4.21), T<sub>7</sub> (4.12) and T<sub>4</sub> (3.85). Treatment T<sub>1</sub> (3.13) recorded the minimum.

It has been recorded from the investigations (Table 8, Fig. 5) that the LAI had increased with the advancement of crop growth with the peak attained at 80 DAS, thereafter it reduced in all the treatments. Treatments T<sub>1</sub> (2.93) and T<sub>7</sub> (2.92) had an average higher LAI.

#### 4.2.2.2 Leaf area duration (LAD) (cm<sup>2</sup>.days)

The treatments differed highly significantly (at1%) among them with respect to LAD throughout the growth period (Table 9, Fig. 6).

### At 40 DAS

The treatment T<sub>7</sub> (4357.08) significantly superseded rest of the treatments for LAD at 40 DAS. T<sub>1</sub> (2702.53) was found to be associated with the lowest magnitude for this trait.

**Table 9: Leaf area duration (LAD) (cm<sup>2</sup>.days) of garden pea during successive growth Intervals in various treatments**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	Average
T <sub>1</sub>	2702.53	10050.60	21707.87	20934.11	13848.78
T <sub>2</sub>	3391.45	9059.63	20153.93	20201.61	13201.65
T <sub>3</sub>	3194.43	10526.73	20720.95	16932.90	12843.75
T <sub>4</sub>	3529.28	8537.88	26874.83	26065.40	16251.84
T <sub>5</sub>	3307.18	8629.28	17006.08	16189.73	11283.06
T <sub>6</sub>	3252.38	11793.88	22087.03	19364.90	14124.54
T <sub>7</sub>	4357.08	10827.38	19304.75	18203.65	13173.21
SEm ±	91.98	555.31	806.64	972.87	606.7
CD 5%	283.42	1711.07	2485.51	2997.7	1869.425

\*DAS – Days after sowing

### **At 60 DAS**

The study showed that the treatment T<sub>6</sub> (11793.88) possessed the maximum leaf area duration though was at par with T<sub>7</sub> (10827.38) and T<sub>3</sub> (10526.73). T<sub>4</sub> (8537.88) recorded the minimum.

### **At 80 DAS**

The treatment T<sub>4</sub> (26874.83) significantly superseded rest of the treatments for LAD at 80 DAS. T<sub>5</sub> (17006.08) was found to be associated with the lowest magnitude for this trait.

### **At 100 DAS**

The treatment T<sub>4</sub> (26065.40) significantly superseded rest of the treatments for LAD at 100 DAS. T<sub>5</sub> (16189.73) was found to be associated with the lowest magnitude for this trait.

Thus the study showed (Table 9, Fig. 6) that the LAD had an increasing trend with the enhancement of crop age till 80 DAS, thereafter it had a reduction in almost all treatments except in T<sub>2</sub> it had a marginal increase. T<sub>4</sub> (16251.84) and T<sub>6</sub> (14124.54) possessed an average higher magnitudes for this character.

#### **4.2.2.3 Crop growth rate (CGR g cm<sup>-2</sup>day<sup>-1</sup>)**

Treatments varied significantly (at 5%) and significantly (at 5%) among them with respect to crop growth rate at 80 DAS and highly significantly (at 15%) during the remaining the investigation period as shown in (Table 10, Fig. 5).

### **At 40 DAS**

The results showed that the treatments T<sub>4</sub> (0.00033), T<sub>7</sub> (0.00028) and T<sub>1</sub> (0.00026) recorded the higher magnitudes for GGR at 40 DAS though they did not differ significantly among them. T<sub>6</sub> (0.00020) recorded lowest value this trait.

### **At 60 DAS**

The results indicated that the higher CGR was recorded in treatment T<sub>2</sub> (0.00086) which was at par with T<sub>1</sub> (0.00085), T<sub>6</sub> (0.00083), T<sub>3</sub> (0.00078) and T<sub>7</sub> (0.00076). T<sub>4</sub> (0.00058) recorded the minimum.

**Table 10: Crop growth rate (CGR g cm<sup>-2</sup>day<sup>-1</sup>) of garden pea during crop life span in various treatments**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.00026	0.00085	0.00116	0.00147	0.00049	0.00085
T <sub>2</sub>	0.00023	0.00086	0.00092	0.00115	0.00151	0.00094
T <sub>3</sub>	0.00021	0.00078	0.00088	0.00079	0.00101	0.00073
T <sub>4</sub>	0.00033	0.00058	0.00120	0.00156	0.00077	0.00089
T <sub>5</sub>	0.00025	0.00072	0.00095	0.00212	0.00143	0.00109
T <sub>6</sub>	0.00020	0.00083	0.00085	0.00102	0.00046	0.00067
T <sub>7</sub>	0.00028	0.00076	0.00105	0.00178	0.00041	0.00085
SEm ±	0.00002	0.00004	0.0001	0.0002	0.0001	0.00009
CD 5%	0.0001	0.0001	0.0002	0.0005	0.0003	0.00024

\*DAS – Days after sowing

#### **At 80 DAS**

The study showed that the treatment T<sub>4</sub> (0.00120) possessed the maximum CGR, though was at par with T<sub>1</sub> (0.00116) and T<sub>7</sub> (0.00105). T<sub>6</sub> (0.00085) recorded the minimum.

#### **At 100 DAS**

The treatments T<sub>5</sub> (0.00212) and T<sub>7</sub> (0.00178) recorded the higher magnitudes for this trait though they did not differ significantly between them. T<sub>3</sub> (0.00079) registered the minimum crop growth rate.

#### **At harvest**

The treatments T<sub>2</sub> (0.00151) and T<sub>5</sub> (0.00143) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>7</sub> (0.00041) registered the minimum CGR.

Thus the study showed (Table 10, Fig. 5) that the CGR had an increasing trend with the enhancement of crop age till 100 DAS, thereafter it had reduction in almost all treatments except in T<sub>2</sub> and T<sub>3</sub> it had a continuous increase till harvest. The average higher was recorded in T<sub>5</sub> (0.00109) and T<sub>2</sub> (0.00094).

#### 4.2.2.4 Relative growth rate (RGR $\text{g g}^{-1}\text{day}^{-1}$ )

The RGR exhibited highly significant variation (at 1%) among different treatments during entire crop growth period under investigation as shown in (Table 11, Fig. 5).

##### At 40 DAS

The treatment T<sub>4</sub> (0.122) significantly superseded rest of the treatments for RGR at 40 DAS. T<sub>2</sub> (0.095) was found to be associated with the lowest magnitude for this trait.

##### At 60 DAS

The study showed that the treatment T<sub>6</sub> (0.078) possessed the maximum RGR, though was at par with T<sub>3</sub> (0.072) and T<sub>2</sub> (0.071). T<sub>4</sub> (0.047) recorded the minimum.

**Table 11: Relative growth rate ( $\text{g g}^{-1}\text{day}^{-1}$ ) of garden pea during crop life span in different treatments.**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	0.100	0.067	0.034	0.024	0.006	0.046
T <sub>2</sub>	0.095	0.071	0.029	0.023	0.020	0.048
T <sub>3</sub>	0.102	0.072	0.031	0.018	0.017	0.048
T <sub>4</sub>	0.122	0.047	0.041	0.026	0.011	0.050
T <sub>5</sub>	0.107	0.064	0.033	0.037	0.016	0.051
T <sub>6</sub>	0.104	0.078	0.029	0.021	0.008	0.048
T <sub>7</sub>	0.104	0.060	0.034	0.030	0.005	0.047
SEm $\pm$	0.003	0.003	0.001	0.002	0.002	0.002
CD 5%	0.009	0.009	0.004	0.006	0.005	0.007

\*DAS – Days after sowing

### **At 80 DAS**

The treatment T<sub>4</sub> (0.041) significantly superseded rest of the treatments for RGR at 80 DAS. T<sub>2</sub> and T<sub>6</sub> (0.029) were found to be associated with the lowest magnitude for this trait.

### **At 100 DAS**

The treatment T<sub>5</sub> (0.037) indicated significant higher RGR over rest of the treatments. Though treatment T<sub>7</sub> (0.030) lagged behind the former but proved significant superiority over the rest except T<sub>4</sub> (0.026) and T<sub>1</sub> (0.024) which were at par. Treatment T<sub>3</sub> (0.018) recorded the minimum.

### **At harvest**

The study showed that the treatment T<sub>2</sub> (0.020) possessed the maximum RGR though was at par with T<sub>3</sub> (0.017) and T<sub>5</sub> (0.016). T<sub>7</sub> (0.005) recorded the minimum.

Thus the results revealed (Table 11, Fig. 5) that the RGR possessed the maximum magnitudes in the early growth phase followed by a subsequent decline in remaining span of growth in all the treatments. T<sub>5</sub> (0.051) and T<sub>4</sub> (0.050) registered the average higher values for this trait.

#### **4.2.2.5 Specific leaf area (SLA) (cm<sup>2</sup> g<sup>-1</sup>)**

The treatments varied highly significantly (at 1%) with respect to specific leaf area throughout the growth period (Table 12, Fig. 6).

### **At 40 DAS**

The results indicated that the higher specific leaf area was recorded in treatment T<sub>7</sub> (366.14) which was at par with T<sub>5</sub> (350.76), T<sub>1</sub> (344.67), T<sub>6</sub> (333.67) and T<sub>2</sub> (331.64). T<sub>3</sub> (289.16) recorded the minimum.

### **At 60 DAS**

The results indicated that the higher specific leaf area was recorded in treatment T<sub>7</sub> (357.64) which was at par with T<sub>2</sub> (331.79), T<sub>1</sub> (331.16), T<sub>6</sub> (321.91) and T<sub>5</sub> (308.35). T<sub>4</sub> (261.87) recorded the minimum.

**Table 12: Specific leaf area (cm<sup>2</sup>g<sup>-1</sup>) of garden pea during crop life span in different treatments**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	Average
T <sub>1</sub>	344.67	331.16	508.02	465.53	412.34
T <sub>2</sub>	331.64	331.79	310.08	268.37	310.47
T <sub>3</sub>	289.16	286.95	372.00	304.81	313.23
T <sub>4</sub>	301.35	261.87	401.43	383.27	336.98
T <sub>5</sub>	350.76	308.35	335.64	281.20	318.99
T <sub>6</sub>	333.67	321.91	347.28	288.84	322.93
T <sub>7</sub>	366.14	357.64	393.33	333.35	362.62
SEm ±	18.02	22.60	19.50	20.75	20.22
CD 5%	55.54	69.70	60.09	63.95	62.32

\*DAS – Days after sowing

#### **At 80 DAS**

The treatment T<sub>1</sub> (508.02) significantly superseded rest of the treatments for SLA at 80 DAS. T<sub>1</sub> (310.08) was found to be associated with the lowest magnitude for this trait.

#### **At 100 DAS**

The treatment T<sub>1</sub> (465.53) indicated significant higher SLA over rest of the treatments. Though treatments T<sub>4</sub> (383.27) and T<sub>7</sub> (333.35) lagged behind the former but proved significant superiority over T<sub>2</sub> (268.37) which had the minimum SLA.

It has been recorded from the investigations that (Table 12, Fig. 6) SLA had a fluctuating trend during the life span of garden pea in different treatments with comparatively higher and lower values during early and later growth span of crop, respectively. The average higher was recorded in T<sub>1</sub> (412.34) and T<sub>7</sub> (362.62).

#### 4.2.2.6 Specific leaf weight (g cm<sup>-2</sup>)

Treatments varied significantly (at 5%) at 100 DAS and highly significantly (at 1%) among treatments during rest of the investigation period as shown in (Table 13, Fig. 5).

##### At 40 DAS

The treatment T<sub>1</sub> (0.0031) significantly superseded rest of the treatments for specific leaf weight at 40 DAS. T<sub>7</sub> (0.0015) was found to be associated with the lowest magnitude for this trait.

##### At 60 DAS

The treatment T<sub>1</sub> (0.0032) indicated significant higher SLW over rest of the treatments. Though treatment T<sub>4</sub> (0.0022) lagged behind the former but proved significant superiority over the rest except T<sub>3</sub> (0.0020) and T<sub>5</sub> (0.0019) which were at par. Treatment T<sub>7</sub> (0.0016) recorded the minimum.

**Table 13: Specific leaf weight (g cm<sup>-2</sup>) of garden pea during crop life span in different treatments.**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	Average
T <sub>1</sub>	0.0031	0.0032	0.0021	0.0025	0.0027
T <sub>2</sub>	0.0017	0.0017	0.0018	0.0022	0.0019
T <sub>3</sub>	0.0019	0.0020	0.0016	0.0025	0.0020
T <sub>4</sub>	0.0019	0.0022	0.0016	0.0021	0.0019
T <sub>5</sub>	0.0016	0.0019	0.0018	0.0024	0.0019
T <sub>6</sub>	0.0017	0.0018	0.0016	0.0021	0.0018
T <sub>7</sub>	0.0015	0.0016	0.0015	0.0019	0.0017
SEm ±	0.0001	0.0001	0.0001	0.0001	0.0001
CD 5%	0.0003	0.0004	0.0002	0.0004	0.0003

\*DAS – Days after sowing

##### At 80 DAS

The treatment T<sub>1</sub> (0.0021) significantly superseded rest of the treatments for specific leaf weight at 80 DAS. Treatment T<sub>7</sub> (0.0015) was found to be associated with the lowest magnitude for this trait.

### At 100 DAS

The results indicated that the higher specific leaf weight was recorded in treatment T<sub>1</sub> and T<sub>3</sub> (0.0025). T<sub>7</sub> (0.0019) recorded the minimum.

The investigations showed (Table 13, Fig. 5) that the SLW had a fluctuating trend in most of the treatments with comparatively higher magnitudes during 60-80 DAS. T<sub>1</sub> (0.0027) and T<sub>3</sub> (0.0020) possessed an average higher SLW.

#### 4.2.2.7 Biomass duration (g days)

The treatments varied highly significantly (at 1%) with respect to biomass duration among treatments throughout the growth period (Table 14, Fig. 6).

### At 40 DAS

The treatments T<sub>4</sub> (17.33) and T<sub>7</sub> (16.18) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (12.68) registered the minimum BMD.

**Table 14: Biomass duration (g days) of garden pea during crop life span in various treatments**

Treatments	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	Average
T <sub>1</sub>	12.68	61.68	160.82	286.64	187.03	141.77
T <sub>2</sub>	13.88	68.05	172.85	290.26	200.87	149.18
T <sub>3</sub>	14.77	77.19	201.82	324.04	209.81	165.53
T <sub>4</sub>	17.33	77.32	185.96	360.27	244.97	177.17
T <sub>5</sub>	14.11	69.12	173.89	352.50	269.98	175.92
T <sub>6</sub>	13.80	78.83	209.28	341.28	217.76	172.19
T <sub>7</sub>	16.18	74.59	183.86	348.26	238.13	172.20
SEm ±	0.49	1.45	5.55	9.08	3.75	4.064
CD 5%	1.51	4.46	17.11	27.97	11.55	12.520

\*DAS – Days after sowing

### **At 60 DAS**

The results indicated that the higher BMD was recorded in treatment T<sub>6</sub> (78.83) which was at par with T<sub>4</sub> (77.32), T<sub>3</sub> (77.19) and T<sub>7</sub> (74.59). T<sub>1</sub> (61.68) recorded the minimum.

### **At 80 DAS**

The treatments T<sub>6</sub> (209.28) and T<sub>3</sub> (201.82) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (160.82) registered the minimum BMD.

### **At 100 DAS**

The results indicated that the higher BMD was recorded in treatment T<sub>4</sub> (360.27) which was at par with T<sub>5</sub> (352.50), T<sub>7</sub> (348.26) and T<sub>6</sub> (341.28). T<sub>1</sub> (286.64) recorded the minimum.

### **At harvest**

The treatment T<sub>5</sub> (269.98) indicated significant higher BMD over rest of the treatments. Though treatment T<sub>4</sub> (244.97) and T<sub>7</sub> (238.13) lagged behind the former but proved significant superiority over T<sub>1</sub> (187.03) which had the minimum BMD.

The results showed (Table14, Fig 6) that the biomass duration had an increasing trend with the enhancement of crop age till 100 DAS thereafter it had reduction in almost all treatments. T<sub>4</sub> (177.17) and T<sub>5</sub> (175.92) possessed an average higher magnitudes for this character.

## **4.3 Other physiological traits**

The results showed (Table 15, Fig. 7) that almost all physiological traits and mechanisms varied highly significantly (at 1%) among treatments except water use efficiency and net photosynthesis rate which exhibited significant differences only at 5% level.

### **4.3.1 Chlorophyll content index**

The results indicated that the higher chlorophyll content index was recorded in treatment T<sub>4</sub> (27.24) which was at par with T<sub>3</sub> (26.92), T<sub>1</sub> (26.14) and T<sub>4</sub> (25.66). Treatment T<sub>2</sub> (19.59) recorded the minimum.

**Table 15: Quantification of physiological traits and mechanisms in different treatments**

Treatments.	Chlorophyll content index	Quantum efficiency	Carboxylation efficiency ( $\mu\text{mol}/\text{m}^2/\text{s}^{-1}$ ( $\mu\text{molmol}^{-1}$ ) <sup>-1</sup> )	WUE ( $\mu\text{mol}/\text{mmol}$ )	Mesophyll Efficiency ( $\mu\text{mol mol}^{-1}$ ( $\text{mol m}^{-2}\text{s}^{-1}$ ) <sup>-1</sup> )	Canopy Temp. ( $^{\circ}\text{C}$ )	Photosynthesis Active Radiation absorption ( $\mu\text{mol m}^{-2}\text{Sec}^{-1}$ )	Net Photosynthesis Rate ( $\mu\text{mol m}^{-2}\text{Sec}^{-1}$ )	Stomatal conductance ( $\text{mol}/\text{m}^2/\text{s}$ )	Transpiration Rate ( $\text{m mol m}^{-2}\text{Sec}^{-1}$ )
T <sub>1</sub>	26.14	0.0816	120.780	49.503	30.170	29.730	1197.330	097.807	0.044	2.220
T <sub>2</sub>	19.59	0.0855	223.943	55.877	17.540	28.290	1199.560	102.463	0.054	1.847
T <sub>3</sub>	26.92	0.0851	158.080	55.817	21.330	28.307	1199.557	102.010	0.042	1.857
T <sub>4</sub>	25.66	0.0849	180.850	55.657	15.003	29.653	1199.880	101.667	0.066	1.883
T <sub>5</sub>	23.86	0.0849	117.380	54.847	19.013	29.010	1199.550	104.197	0.062	1.960
T <sub>6</sub>	24.47	0.0848	95.877	59.370	16.210	29.347	1200.000	102.507	0.095	1.723
T <sub>7</sub>	27.24	0.0905	82.793	66.393	15.703	29.043	1200.220	108.663	0.099	1.647
SEm ±	0.659	0.001	18.426	2.39	1.91	0.24	0.4	1.71	0.01	0.05
CD 5%	2.03	0.003	56.777	7.38	5.9	0.74	1.22	5.26	0.02	0.16

#### **4.3.2 Quantum efficiency**

The treatment T<sub>7</sub> (0.0905) significantly superseded rest of the treatments for quantum efficiency. Treatment T<sub>1</sub> (0.0816) was found to be associated with the lowest magnitude for this trait.

#### **4.3.3 Carboxylation efficiency**

The treatments T<sub>2</sub> (223.943) and T<sub>4</sub> (180.85) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>7</sub> (82.793) registered the minimum carboxylation efficiency.

#### **4.3.4 Water use efficiency**

The treatments T<sub>7</sub> (66.39) and T<sub>6</sub> (59.37) recorded the higher magnitudes for this trait though they did not differ significantly between them. T<sub>1</sub> (49.50) registered the minimum water use efficiency.

#### **4.3.5 Mesophyll Efficiency**

The treatment T<sub>1</sub> (30.17) indicated significant higher mesophyll efficiency over rest of the treatments. Though treatment T<sub>3</sub> (21.33) lagged behind the former but proved significant superiority over the rest except T<sub>5</sub> (19.01) and T<sub>2</sub> (17.54) which were at par. T<sub>4</sub> (15.00) recorded the minimum.

#### **4.3.6 Canopy Temperature**

The results indicated that the higher Canopy Temperature was recorded in treatment T<sub>1</sub> (29.73) which was at par with T<sub>4</sub> (29.65), T<sub>6</sub> (29.34), T<sub>7</sub> (29.04) and T<sub>5</sub> (29.01). Treatment T<sub>2</sub> (28.29) recorded the minimum.

#### **4.3.7 Photosynthesis Active Radiation absorption**

The results indicated that the higher PAR absorption was recorded in treatment T<sub>7</sub> (1200.2) which was at par with T<sub>6</sub> (1200.0), T<sub>4</sub> (1199.9) and T<sub>2</sub>, T<sub>3</sub> and T<sub>5</sub> (1199.6). Treatment T<sub>1</sub> (1197.3) recorded the minimum.

#### **4.3.8 Net Photosynthesis Rate**

The treatments T<sub>7</sub> (108.66) and T<sub>5</sub> (104.2) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (97.80) registered the minimum.

#### **4.3.9 Stomatal conductance**

The treatments T<sub>7</sub> (0.099) and T<sub>6</sub> (0.095) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>3</sub> (0.042) registered the minimum Stomatal conductance.

#### **4.3.10 Transpiration Rate**

The treatment T<sub>1</sub> (2.220) significantly superseded the rest of the treatments for transpiration rate. Treatment T<sub>7</sub> (1.647) was found to be associated with the lowest magnitude for this trait.

### **4.4 Yield and yield contributing attributes**

The results indicated (Table-16, Fig 8 and 9) that almost all yield components varied highly significantly (at 1%) among treatments, except HI which differed significantly only at 5% level. However, the remaining components did not indicate any significant difference among treatments.

#### **4.4.1 Plant height (cm.)**

The results showed that the treatments T<sub>1</sub> (81.87), T<sub>6</sub> (81.74) and T<sub>2</sub> (78.80) recorded the higher magnitudes for this trait though they did not differ significantly among them. Treatment T<sub>4</sub> (73.87) recorded lowest value for this character.

#### **4.4.2 Number of nodes plant<sup>-1</sup>**

The results indicated that the treatment T<sub>5</sub> (22.30) noted the maximum number of nodes/plant though did not vary significantly with T<sub>4</sub> (21.67) and T<sub>7</sub> (20.53). T<sub>1</sub> noted the minimum number of nodes/plant (15.07).

#### **4.4.3 Number of pods plant<sup>-1</sup>**

The study showed that the treatment T<sub>4</sub> (21.53) possessed the maximum number of pods though was at par with T<sub>5</sub> (21.40) and T<sub>7</sub> (18.93). Treatment T<sub>1</sub> (14.80) recorded the minimum number of pods.

#### **4.4.4 Number of filled pods plant<sup>-1</sup>**

The study indicated that treatments T<sub>5</sub> (20.83), T<sub>4</sub> (20.80) and T<sub>7</sub> (18.33) recorded the higher magnitudes for this trait though they did not vary significantly among them. T<sub>1</sub> (14.27) possessed the minimum.

**Table 16: Yield and yield contributing attributes in different treatments in garden pea**

Treatments	Plant height (cm)	No. of nodes plant <sup>-1</sup>	No. of pods plant <sup>-1</sup>	No. of filled pods plant <sup>-1</sup>	No. of empty pods plant <sup>-1</sup>	No. of seeds pod <sup>-1</sup>	100 seeds weight (g)	Pod length (cm)	Pod width (mm)	Pod girth (mm)	Green pod yield g plant <sup>-1</sup>	Seed yield		Biological yield		Harvest index (%)
												g plant <sup>-1</sup>	Kg ha <sup>-1</sup>	g plant <sup>-1</sup>	Kg ha <sup>-1</sup>	
T <sub>1</sub>	81.87	15.07	14.80	14.27	0.53	3.83	23.55	6.90	9.60	3.20	59.69	10.53	1660.26	23.41	3660.26	45.47
T <sub>2</sub>	78.80	16.13	16.73	15.93	0.80	4.23	23.75	7.23	9.92	3.31	68.23	13.37	1916.67	25.17	3820.51	50.36
T <sub>3</sub>	74.67	16.13	16.00	15.20	0.80	4.26	23.47	7.21	10.37	3.46	65.52	12.40	1891.03	19.90	3352.99	56.41
T <sub>4</sub>	73.87	21.67	21.53	20.80	0.73	4.49	24.44	7.43	10.19	3.40	75.30	16.79	1987.18	34.22	4205.13	47.30
T <sub>5</sub>	77.07	22.30	21.40	20.83	0.57	4.51	24.46	7.81	10.58	3.53	105.04	18.31	2038.46	29.53	4155.98	49.05
T <sub>6</sub>	81.47	16.67	15.60	15.07	0.54	4.11	23.47	7.59	10.86	3.62	61.68	12.16	1770.09	23.50	3735.04	47.47
T <sub>7</sub>	77.87	20.53	18.93	18.33	0.60	4.32	23.83	7.35	10.83	3.61	70.87	14.89	1925.21	27.48	3826.92	50.54
SEm±	1.22	1.03	0.93	0.98	0.07	0.08	0.22	0.11	0.17	0.31	3.05	0.84	36.39	1.48	124.04	1.94
CD 5%	3.77	3.16	2.87	3.01	-	0.24	-	0.33	0.53	-	9.39	2.59	112.12	4.56	382.20	5.98

#### **4.4.5 Number of empty pods plant<sup>-1</sup>, Seed index (g), Pod girth (mm)**

Seed index (g), number of empty pods/plant and pod girth (mm.) though the treatments did not show any significant difference for this traits but treatment T<sub>5</sub> (24.46g) and T<sub>1</sub> (23.55g) for seed index, T<sub>6</sub> (3.61mm.) and T<sub>1</sub> (3.20mm.) for pod girth and T<sub>2</sub> (0.80) and T<sub>1</sub> (0.53) for number of empty pods/plant shared the maximum and minimum values for this traits, respectively.

#### **4.4.6 Number of seeds pod<sup>-1</sup>**

The study showed that the treatment T<sub>5</sub> (4.51) possessed the maximum number of seeds/pod though was at par with T<sub>4</sub> (4.49) and T<sub>7</sub> (4.32). Treatment T<sub>1</sub> (3.83) recorded the minimum number of seeds/pod.

#### **4.4.7 Pod length (cm)**

The treatments T<sub>5</sub> (7.81) and T<sub>6</sub> (7.59) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (6.90) registered the minimum pod length.

#### **4.4.8 Pod width (mm)**

The results indicated that the higher pod width was recorded in treatment T<sub>6</sub> (10.86) which was at par with T<sub>7</sub> (10.83), T<sub>5</sub> (10.58) and T<sub>3</sub> (10.37). Treatment T<sub>1</sub> (9.60) recorded the minimum.

#### **4.4.9 Green pod yield (g plant<sup>-1</sup>)**

The treatment T<sub>5</sub> (105.04) indicated significant higher green pod yield over rest of the treatments. Treatments T<sub>4</sub> (75.30), T<sub>7</sub> (70.87) and T<sub>2</sub> (68.23) did not differ significantly among them. T<sub>1</sub> (59.69) recorded the minimum.

#### **4.4.10 Seed yield (g plant<sup>-1</sup>)**

The treatment T<sub>5</sub> (18.31) significantly superseded the rest of the treatments for seed yield. Though T<sub>4</sub> (16.79) had the lower values as compared to the former but was at par with T<sub>7</sub> (14.89). Treatment T<sub>1</sub> (10.53) was found to be associated with the lowest magnitude for this trait.

#### **4.4.11 Seed yield (kg ha<sup>-1</sup>)**

The treatments T<sub>5</sub> (2038.46) and T<sub>4</sub> (1987.18) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (1660.26) registered the minimum pod length.

#### **4.4.12 Biological yield (g plant<sup>-1</sup>)**

The treatment T<sub>4</sub> (34.22) indicated higher biological yield over rest of the treatments though was at par with T<sub>5</sub> (29.53) T<sub>7</sub> (27.48) and T<sub>2</sub> (25.17) was did not differ significantly among them. Treatment T<sub>3</sub> (19.90) had the lowest biological yield.

#### **4.4.13 Biological yield (kg ha<sup>-1</sup>)**

The results showed that treatments T<sub>4</sub> (4205.13), T<sub>5</sub> (4155.98) and T<sub>7</sub> (3826.92) possessed the higher biological yields but they were at par were them. Treatment T<sub>3</sub> (3352.99) had the lowest biological yield.

#### **4.4.14 Harvest Index (%)**

The treatment T<sub>3</sub> (56.41) possessed maximum harvest index though did not vary significantly with T<sub>7</sub> (50.54). Treatment T<sub>1</sub> (45.47) recorded the lowest harvest index.

Thus the investigations revealed (Table 16, Fig.8 and 9 ) that treatment T<sub>5</sub> (Soil application of Potassium humate- 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + soil application of Potassium humate - 4.5@ 5 lit. in 150 lit. of water + after 30 days of first application + foliar spray of Potassium humate - 4.5@ 3 lit. in 150 lit. of water after 45 days of 2<sup>nd</sup> application) outyielded (green pod yield 105.04 g plant<sup>-1</sup>, seed yield 18.31 g plant<sup>-1</sup> and 2038.46 kg ha<sup>-1</sup>) other treatments (75.97% higher for green pod yield g plant<sup>-1</sup> and 22.77% for seed yield kg ha<sup>-1</sup> over control) owing to the maximum number of nodes plant<sup>-1</sup> (22.30), filled pods plant<sup>-1</sup> (20.83), number of seeds pod<sup>-1</sup> (4.51), 100 seed weight (24.46 g and a quite higher number of pods plant<sup>-1</sup> (21.53) reflected in its maximum economic productivity.

Treatment T<sub>4</sub> (Soil application of Potassium humate - 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate - 4.5@ 5 lit. in 250 lit. of water after 45 days of 1<sup>st</sup> application) was adjudged

as second in yield performance (green pod yield 75.30 g plant<sup>-1</sup>, seed yield 16.79 g plant<sup>-1</sup> and 1987.18 kg ha<sup>-1</sup>). This was attributed to its maximum number of pods plant<sup>-1</sup> (21.53), biological yield (34.22 g plant<sup>-1</sup> and 4205.13 kg ha<sup>-1</sup>), and a quite higher number of nodes plant<sup>-1</sup> (21.67), number of filled pods plant<sup>-1</sup> (20.80), number of seeds pod<sup>-1</sup> (4.49), 100 seed weight (24.44 g). Control recorded the lowest yield (green pod yield 59.69 g plant<sup>-1</sup>, seed yield 10.53 g plant<sup>-1</sup> and 1660.26 kg ha<sup>-1</sup>) which was attributed to the low performance of almost all yield components.

#### 4.5 Proximate analysis

The biochemical constituents indicated highly significant variations (at 1%) among different treatments in dry seeds (Table 17, Fig. 10).

##### 4.5.1 Protein (%)

The results indicated that the higher protein (%) was recorded in treatment T<sub>5</sub> (20.96) which was at par with T<sub>4</sub> (20.32) and T<sub>7</sub> (19.98). T<sub>1</sub> (18.20) recorded the minimum.

**Table17: Biochemical constituents of garden pea in different treatments**

Treatments	Protein (%)	Carbohy drate (%)	Crude Fiber (%)	Fat (%)	Ash (%)
T <sub>1</sub>	18.2	43.25	18.89	5	3.12
T <sub>2</sub>	18.4	42.16	19.34	4.36	3.45
T <sub>3</sub>	18.9	42.21	19.62	4.98	3.2
T <sub>4</sub>	20.32	42.45	18.23	5.78	2.12
T <sub>5</sub>	20.96	42.34	18.12	5.25	2.78
T <sub>6</sub>	19.15	42.78	19.36	4.75	3.74
T <sub>7</sub>	19.98	42.16	19.18	4.27	3.98
SEm±	0.1	0.15	0.1	0.21	0.09
CD 5%	0.4	0.45	0.4	0.64	0.27

#### **4.5.2 Carbohydrate (%)**

The treatment T<sub>1</sub> (43.25) indicated significant higher carbohydrate content over rest of the treatments. Though treatment T<sub>6</sub> (42.78) lagged behind the former but proved significant superiority over the rest except T<sub>4</sub> (42.45) and T<sub>5</sub> (42.34) which were at par. T<sub>7</sub> (42.16) recorded the minimum.

#### **4.5.3 Crude Fiber (%)**

The study showed that the treatment T<sub>3</sub> (19.62) possessed the maximum crude fiber content though was at par with T<sub>6</sub> (19.36) and T<sub>2</sub> (19.34). T<sub>5</sub> (18.12) recorded the minimum.

#### **4.5.4 Fat (%)**

The treatment T<sub>4</sub> (5.78) significantly superseded rest of the treatments for fat. (%) T<sub>7</sub> (4.27) was found to be associated with the lowest magnitude for this trait.

#### **4.4.5 Ash (%)**

The treatments T<sub>7</sub> (3.98) and T<sub>6</sub> (3.74) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>4</sub> (2.12) registered the minimum ash content.

## DISCUSSION

Potassium humate 4.5 is a complex organic molecule formed by the breakdown of organic matter in soil by micro-organisms and it is not a fertilizer. It is found in forest soil 2 - 3% and rich in oxidized low rank coal, lignite, peat etc., major constituents of carbon and oxygen about 90%. Using Potassium humate has a variety of benefits and it is applicable for all type of crops. It is a root growth promoter, increases chlorophyll content, enhances plant growth particularly biomass production, improves plant quality, good plant growth stimulant. It increases nutrient uptake, acting on soil and plants. Our land lost its fertility due to prolonged and excess use of chemical fertilizers and pesticides. It improves physical property of soil, ion exchange capacity, water holding capacity and drought tolerance ability. This also prevents loss of nutrients from soil and act as a storehouse by keeping plant nutrients in soil. It increases crop yield and reduces the use of pesticide and chemical fertilizers. Our Indian soils are low in organic carbon. Due to intensive cultivation; organic matter and other nutrients are depleted from the soil. To compensate this, traditionally organic manure, composite, vermin compost and green manure are used in large quantities to achieve humic acid content in the soil. Application of Potassium humate helps to build up organic matter content in the soil, enhancing water retention, cation exchange capacity, plant growth stimulant and helps to improve the yield of crops. Chemical composition of humic acid (HA) Soluble Potassium humate: 80% humic acid, 11-13% K<sub>2</sub>O, 5-7% moisture, 83 g/100ml<sup>-1</sup> bulk density, > 98 % water solubility.

The discussion on influence of Potassium humate on growth and productivity in garden pea is being divided under the following subheads;

5.1 Phenophases

5.2 Physiological studies

5.2.1 Dry matter production and partitioning in plant parts (leaves, stems, tendrils and pods etc.)

5.2.2 Growth analytical studies

5.3 Other physiological traits and mechanisms

5.4 Yield and yield contributing attributes

5.5 Proximate analysis

## **5.1 Phenophases**

### **5.1.1 Days to seedling emergence**

The present study revealed (Table 2, Fig. 3)) that the treatment T<sub>4</sub> (soil application of Potassium humate 4.5@ 5 litre/acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate 4.5@ 5 litre in 250 litre of water after 45 days of first application) possessed the late seedling emergence (5.0 days), on the other hand treatment T<sub>5</sub> (soil application of Potassium humate 4.5@ 5 litre/acre before the basal dose of manure/fertilizer + soil application of Potassium humate 4.5@ 5 litre in 150 litre of water + after 30 days of first application + foliar spray of Potassium humate 4.5@ 3 litre in 150 litre of water after 45 days of second application) was found to be associated with the earliest emergence of seedling (4.0 days).

The early seedling emergence has the advantage of attaining the longer crop duration which may have the better chances of producing higher economic yield due to a quite longer period of solar energy interception.

### **5.1.2 Days to 2 to 4 leaf stage**

The present results showed (Table 2, Fig. 3) that the treatment T<sub>1</sub> (only normal package of practices without application of Potassium humate (control)) had the delayed 2-4 leaf stage (12 days) as compared to other treatments, whereas the treatment T<sub>7</sub> (soil application of Potassium humate 4.5@ 5 litre/acre before the basal dose of manure/Fertilizer + foliar spray of Potassium humate 4.5@ 5 litre in 250 litre of water after 15 days of first picking) recorded the earliest attainment of this stage (10.0 days). Normally the early leaf formation has the benefit of acquiring more time to cover the soil with the assimilatory surface area for interception of solar energy.

### **5.1.3 Days to tendrill formation**

The poor growth of semi-leafless and tare-leaved types was attributed to increasing tendrill size (Armstrong and Patel, 1994).

From the early investigations it appeared that the higher growth of tendrill is found to be associated with the reduced plant growth. In the present study (Table 2, Fig. 2) it has been recorded the treatment T<sub>3</sub> (soil application of Potassium humate 4.5@ 5 litre/acre before the basal dose of manure/fertilizer + Second soil application 5liter/with150 litre of water one month of the first application) had the delayed tendrill formation (16.0 days) and T<sub>7</sub> the earliest.

### **5.1.4 Days to 1<sup>st</sup> flower initiation**

The significant correlation of early days to flower initiation with yield would be more effective for improving green pod yield in garden pea (Kumar et al., 2008). The flower initiation is an important phenological stage which determines the plant productivity in pigeonpea (Bhattacharya and Sharma, 2001). The seed yield was positively and directly influenced by days to flower initiation in chick pea (Adhikari and Pandey, 1982). In garden pea a high positive significant correlation of days to first picking with node number was noted at which first flower appear (Sharma and Sharma, 2012). The highly significant difference was noted in the genotypes for days to 1st flower emergence in garden pea (Pal and Singh, 2012).

The present study indicated (Table 2, Fig. 3) that the treatment T<sub>7</sub> recorded the minimum time (33.0 days) to achieve this stage, on the other hand T<sub>1</sub> indicated the highest period (35.67 days) to acquire this stage. The early flower initiation provides the plants to have higher span of reproductive period which may enhance the economic output provided the seed formation occurs early and grain filling rate is optimum.

### **5.1.5 Days to 50% flowering**

Days to 50 % flowering were the major yield-contributing characters and will help in improving the seed yield in garden pea (Katore and Navale, 2010). In garden pea a high positive significant correlation of days to 50%

flowering suggested that these genotypes were early flowering genotypes (Sharma and Sharma, 2012). The highly significant difference was noted in garden pea genotypes for days to 50% flower emergence (Pal and Singh, 2012). In pigeon pea the harvest index had high positive direct effect on days to 50% flowering (Kumar et al., 2013).

The investigations indicated (Table 2, Fig. 3) that the treatment T<sub>7</sub> took the minimum time (38.33 days) and T<sub>1</sub> maximum (41.76 days) time to attain this stage. The early flowering is beneficial for plants to produce more economic yield subject to the availability of other factors in abundance during remaining period of growth.

#### **5.1.6 Days to pod initiation**

There was a highly significant difference in the garden pea genotypes for days to 1<sup>st</sup> pod set in garden pea (Pal and Singh, 2012).

The present study showed (Table 2, Fig. 3) that the treatment T<sub>6</sub> (soil application of Potassium humate 4.5@ 5 litre/acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate 4.5@ 5 litre in 250 litre of water immediately after first picking) recorded minimum time (40.0 days) for pod initiation, on the hand treatment T<sub>1</sub> had the significant more days (43.33 days) for achieving this stage. Longer duration of pod set provides the optimum time to the pod for its extension which facilitates seed to expend conveniently without mechanical resistance provided by the pod.

#### **5.1.7 Days to seed formation**

Results showed (Table 2, Fig. 3) that the treatment T<sub>7</sub> was found to be associated with the earliest seed formation (47.0 days), whereas T<sub>1</sub> was found to be associated with the maximum time (50.67 days) required for the seed formation. The longer seed filling period has been found to be associated with the higher seed yield in many investigations.

#### **5.1.8 Days to 1<sup>st</sup> picking**

The greater emphasis should be given to characters like days to first green pod harvest (Kumar and Sharma, 2006). The pod yield plant<sup>-1</sup> exhibited a significant and positive correlation with number of days to first picking

(Kumar et al., 2003). The number of pods plant<sup>-1</sup> had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea (Ramesh and Tewatia, 2002).

The present investigations revealed (Table 2, Fig. 3) that the treatment T<sub>7</sub> took minimum time to acquire this stage (68.0 days) which is beneficial for facilitating more number of pickings in garden pea enhancing the market value of the produce. T<sub>4</sub> showed the maximum time (79.33 days) to exhibit this stage.

#### **5.1.9 Days to Physiological maturity**

The effects of low temperatures on seed weight showed a negative response to mean temperature during the grain-filling phase (Poggio et al., 2005). At physiological maturity in soybean genotypes 4-10.66 leaves plant<sup>-1</sup> were retained by the genotypes and the colour of the pods and stem became dark red brown to brown (Gontia et al., 1995). After physiological maturity assimilates were not partitioned towards sink from the source, because vascular connection to the sink is broken by formation by abscission layer (Eastin et al., 1973).

The present study indicated (Table 2, Fig. 3) that treatment T<sub>7</sub> recorded the minimum time (100.67 days) to attain this stage which suggested that the treatment had reduced the time to harvest as it has been observed that the crops produce more economic yields with high seed vitality and vigour it should harvested at the time of physiological maturity. Treatment T<sub>4</sub> was found to be associated with more number of days (106.0 days) to acquire this stage.

#### **5.1.10 Days to physical maturity**

The days to maturity was the major yield-contributing character and will help in improving the seed yield in garden pea (Katore and Navale, 2010). In soybean among morphological traits under water stress conditions, the days to maturity showed the maximum reduction (94%) (Shadakshari et al., 2014). The green pod yield and seed yield per plant was found to be significantly and positively with days to maturity (Kumar et al., 2008 and Kumar et al., 2014). On the contrary, Kumar et al. (2012) reported that the seed yield per plant had

the significant and negative association with days to maturity. Pal and Singh (2012) reported the highly significant difference in the genotypes for days to maturity of edible green pod in garden pea. The days to maturity showed a significant association with 100-grain weight and number of seeds per pod (Kumar et al., 2003).

The results indicated that (Table 2, Fig. 3) the treatment T<sub>7</sub> required the minimum time (106.33 days) to attain this stage, on the other hand T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> achieved this stage at the longest period (111.33 days). The crop of short duration is only beneficial when there is no decline in the economic productivity. Therefore, obtaining the crop of short duration with higher economic yield is the challenge for the agricultural scientists during the current scenario.

Thus the investigations revealed that the treatment T<sub>2</sub> (76.66 days) was found to be associated with the longest reproductive period, whereas T<sub>5</sub> (74.66 days) recorded a quite less time for this period. On the other hand T<sub>4</sub> (61.66 days) had the longest seed filling period, whereas T<sub>5</sub> (60.00 days) recorded the minimum time for seed filling. Treatment T<sub>1</sub> (37.34 days) had the longest vegetative phase and T<sub>7</sub> (33.66 days) shortest. Though the treatment T<sub>5</sub> had the shot duration for reproductive period (74.66 days) as well as seed filling (60.00 days) still yielded higher which may be attributed to the rapid rate of seed filling influenced by the treatment. It has also been noticed that all the treatments with Potassium humate were found to reduce the vegetative phase and increase span of reproductive phase. Beside, the treatments with the same substance were also found to improve mobilization efficiency of photo-assimilates from the source to the sink.

## **5.2 Physiological observations:-**

### **5.2.1 Dry matter production and partitioning**

#### **5.2.1.1 Dry matter production in leaves (g plant<sup>-1</sup>)**

The present study indicated (Table 3, Fig. 4) that the leaves dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined which was attributed to the drying and senescence of leaves and transport of photosynthates from the source to the

sink. Treatments T<sub>6</sub> (2.18g) and T<sub>2</sub> (2.11g) were associated with an average higher DM production in leaves. It appeared that the application of Potassium humate by different methods increased dry matter production which may be due to its direct action on plant growth auxin activity, contributing to increase in the leaves dry matter in pea (Singaroval et al., 1993). The foliar application with humic acid @2 g L<sup>-1</sup> increased leaves dry weight in the two growing seasons (Gad El-Hak, 2012).

#### **5.2.1.2 DM accumulation in main stem (g plant<sup>-1</sup>)**

The timing of crop maturity is largely determined by the capacity of the plant to continue the production of new fruiting sites, stem dry matter production could be impinged both on the timing of crop maturity and yield (Bange and Milroy, 2004). The humic acid increased dry matter production might be due to its direct action on plant growth auxin activity, contributing to increase in the stem dry matter in pea (Singaroval et al., 1993).

In the present study (Table 4, Fig. 4) it was recorded that stem dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it had a fluctuating trend till maturity. The fluctuation of dry matter in stem in later growth phases was attributed to the increased competition among various plant parts for photo-assimilates during this growth period. All the treatment were found to enhance the dry matter accumulation in stem with the maximum magnitudes were recorded in T<sub>5</sub> (2.71) and T<sub>7</sub> (2.70). In peas stem dry weight recorded the highest values by foliar application with humic acid @ of 100 mg+herbicides (Senesi, 1994). The stem dry weight was significantly increased by foliar spray with humic acid @1.0 g L<sup>-1</sup> in eggplant (Padem, 1999). The foliar application with humic acid @2 g L<sup>-1</sup> increased stem dry weight in the two growing seasons (Gad El-Hak, 2012). The significant effect was noted on stem dry matter of mungbean with the application of HA as soil application (Ashraf et al., 2005).

#### **5.2.1.3 DM accumulation in tendrils (g plant<sup>-1</sup>)**

The total net photosynthesis of the tendrils of semi-leafless types was similar to that of leaflets of conventional types, due to larger dry weight of tendrils compensating for poor photosynthetic rates (Armstrong and Patel, 1994).

The present study indicated (Table 5, Fig. 4) that the tendril dry matter had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined. The decline in the tendril dry weight in the later growth phases with the increase in dry weight of other parts particularly economic sinks suggested that the dry matter might have gone to other parts of the plant from the tendril. Treatment T<sub>4</sub> (0.27) and T<sub>7</sub> (0.23g) were associated with an average higher DM production in tendril.

#### **5.2.1.4 DM accumulation in pods (g plant<sup>-1</sup>)**

The dry matter accumulation was greater for short and later maturing cultivars compared to the tall and early maturity or mid-season cultivars. Grain yield was positively and significantly correlated with pod dry matter accumulation (Ntanos et al., 2002).

The present study indicated (Table 6, Fig. 4) that the pod dry matter had a continuous increase with the advancement of crop growth till maturity in all the treatments. The increase was associated with the decreased dry matter of other parts of the plants particularly assimilatory apparatus. All the treatments have been reported to increase the dry matter accumulation in the pods over control. Treatments T<sub>5</sub> (11.21) and T<sub>4</sub> (10.46) were associated with an average higher DM production in pods. The application of Potassium humate increased dry matter production might be due to its direct action on plant growth auxin activity, contributing to increase the pod dry matter in pea (Singaroval et al., 1993). In peas pod dry weight recorded the highest values by foliar application with humic acid @ of 100 mg+herbicides (Senesi 1994). The pod dry weight was significantly increased by foliar spray with humic acid @ of 1.0 g/L in eggplant (Padem, 1999). The significant effect was observed on pod dry matter of mungbean with the application of HA as soil application (Ashraf et al., 2005). Positive correlation was noted between yield and dry matter accumulation in seeds (Jun et al., 2006). The foliar application with humic acid @2 g L<sup>-1</sup> increased pod dry weight in the two growing seasons (Gad El-Hak, 2012).

#### **5.2.1.5 Total dry matter production (gplant<sup>-1</sup>)**

The total dry matter production by a crop may vary according to the changes in either the size of photosynthetic system or in its activity, as well as in the length of the growth period during which photosynthesis continues

(Timmannavar and Patil, 2000). The plant dry matter accumulation depends on the total C fixed during photosynthesis and the action of the carbon converted into dry matter (Rao et al., (2012). The increased pea sowing rates increased total dry matter (Munakamwe et al., 2012). In garden pea the highest yield among the genotypes was due to higher total dry matter (Gavit et al., 2008). The total dry weight increased in all vegetation period in chickpea (Karim and Fattah, 2007).

The present investigations showed (Table 7, Fig. 4) that the TDM had a continuous increase with advancement of crop age till maturity in most of the treatments except in T<sub>6</sub> it was reduced at harvest. The decreasing total dry matter in T<sub>6</sub> may be attributed to the excessive senescence and drying of leaves and chemical desiccation of various compounds of plants as a result of ageing (Haley and Quick, 1998). It appeared that all the treatments have increased the dry matter production attributed to its direct action on plant growth auxin activity contributing to increase in dry matter production (Singaroval et al., 1993). Treatments T<sub>5</sub> (12.36) and T<sub>4</sub> (11.48) had average maximum TDM production (g/plant). In peas total plant dry weight exhibited the highest values by foliar application with humic acid @100 mg+herbicides (Senesi, 1994). The total plant dry weight was significantly increased by foliar spray with humic acid @1.0 g L<sup>-1</sup> in eggplant (Padem, 1999). The significant effect was observed on total dry matter of mungbean with the application of HA as soil application (Ashraf et al., 2005). The total dry weight was significantly increased at the concentration of 100 ppm humic acid and 300 kg h<sup>-1</sup>a potassium (Motaghi et al., 2014).

## **5.2.2 Growth analytical parameters**

### **5.2.2.1 Leaf area index (LAI)**

The leaf photosynthetic rate and leaf area index appeared to be major determinants of crop growth rate (Timmannavar and Patil, 2000). The greater emphasis should be given to characters like leaf area index (Kumar and Sharma, 2006). The increase in dry matter is associated with increase in LAI to a stage where the mutual shading of leaves does not take place after that with increasing LAI the dry matter accumulation decreases (Watson, 1952). In garden pea the highest yield among the genotypes was due to higher leaf

area index (Gavit et al., 2008). Deshmukh and Patil (1995) noted the significant positive correlation values for mean LAI with CGR. This indicates the importance of leaf area in increasing the rate of photosynthesis.

The present study showed (Table 8, Fig. 5) that the LAI had increased with the advancement of crop growth with the peak attained at 80 DAS there after it reduced in all the treatments. The reduction in LAI after 80 DAS was attributed to the drying and senescence of leaves and movement of photo-assimilates from the source to the developing sink. Treatment T<sub>1</sub> (2.93) and T<sub>7</sub> (2.92) had an average higher LAI. The differences in the leaf area index of the genotypes examined were not significant. Leaf area index ranged from 0.54 to 3.17 (Rajput et al., 2004).

#### **5.2.2.2 Leaf area duration (LAD) (cm<sup>2</sup>.days)**

The leaf area duration represents the persistence of leaf area during crop growth span. The leaves remain active during the longer period of time will have more time to absorb solar radiation and produce the assimilates. If these photosynthetic products are translocated at the optimum rate to the sink at proper time, this will enhance the economic productivity of the plant.

The present investigations showed (Table 9, Fig. 6) that the LAD had increased continuously with the advancement of the crop duration and after attaining a peak at 80 DAS it declined which is attributed to the reduction in LAI during this period, however in treatment T<sub>2</sub> it had a marginal increase at 100 DAS which is a beneficial information regarding the use of this treatment for enhancing the duration of persistence of assimilatory surface area. The senescence of leaves at maturity reduced the CGR, LAI, and LAD and consequently the rate of dry matter accumulation (Singh Agarwal, 2001). The LAD (Leaf Area Duration) was decreased to first pod setting in chickpea (Karim and Fattah, 2007). T<sub>4</sub> (16251.84) and T<sub>6</sub> (14124.54) were found to be associated with an average higher magnitudes for this character.

#### **5.2.2.3 Crop growth rate (CGR g cm<sup>-2</sup> day<sup>-1</sup>)**

The CGR can be analysed as the product of incident light receipt efficiency of light penetration and efficiency of use of intercepted light in dry matter production (Warren and Wilson, 1981). In garden pea a significantly

higher CGR, the leaf area ratio showed a similar trend but the RGR and NAR were higher in Arkel. No definite pattern with regard to sowing dates was observed. Variations in different growth parameters were more common during the period between full bloom to 50% pod harvest than between 30 days after sowing to full bloom (Srivastava and Singh, 1989). In garden pea the highest yield among the higher crop growth rate (Gavit et al., 2008). The yield significantly and positively correlated with crop growth rate (CGR) during the 20 d period after the beginning of seed filling (R5), i.e. initial seed filling stage. The correlation of seed yield with CGR varied with the year from negative to positive correlations (Shiraiwa et al., 2004).

The present study indicated (Table 10, Fig. 5) that the CGR had an increasing trend with the enhancement of crop age till 100 DAS, thereafter it had reduction in almost all treatments except in T<sub>2</sub> and T<sub>3</sub> it had a continuous increase till harvest. The average higher was recorded in T<sub>5</sub> (0.00109) and T<sub>2</sub> (0.00094). The increase of CGR in treatment T<sub>2</sub> and T<sub>3</sub> was attributed to the higher magnitude of LAI and LAD even during the later phases of growth. The crop growth rate gradually increases with crop age and reached its peak during 70 to 90 days, thereafter declined (Pal et al., 1996). The CGR increased highly with advancement in plant age but decreased at ripening (Tiwari et al., 1996). The CGR (Crop Growth Rate) was increased to pod filling period in chickpea (Karim and Fattah, 2007). The Potassium humate treated plants showed more vegetative growth than control plants (untreated plants) (Patil et al., 2010).

#### **5.2.2.4 Relative growth rate (RGR g g<sup>-1</sup> day<sup>-1</sup>)**

The RGR varied significantly in all the tested varieties. Though the genotypes differ in the yield potentiality, the varieties being within the same species did not vary significantly among each other with respect to RGR (Sarkar et al., 2004). The higher planting density decreased relative growth rate by 24% (Mahon, 1990). In garden pea the cultivar and sowing date affected significantly the relative growth rate (RGR) (Jamil et al., 2006).

The present study indicated that (Table 11, Fig. 5) the relative growth rate had the higher magnitudes during early growth span in all the treatments

thereafter it declined in later growth phase due to reduction in magnitudes of LAI, LAD and CGR. The RGR represents increment in existing biomass which may be crucial during a prominent period of growth. T<sub>5</sub> (0.051) and T<sub>4</sub> (0.050) possessed an average higher RGR during entire growth phase of the crop. The higher magnitudes in the early growth phase may be resultant of higher magnitude of assimilatory surface area which might have facilitated the interception of higher amount of solar radiation resulted in higher biomass production a subsequently higher RGR.

#### **5.2.2.5 Specific leaf area (SLA) (cm<sup>2</sup> g<sup>-1</sup>)**

The SLA possessed the positive association with the grain yield (Sahoo and Guru, 1998).

It has been recorded from the investigations (Table 12, Fig. 6) that SLA had a fluctuating trend during the life span of garden pea in different treatments with comparatively higher and lower values during early and later growth span of crop, respectively. The higher magnitudes in the early growth phase was attributed to the higher enhancement of assimilatory surface area as compared to the dry matter production per unit leaf area. However, in the later growth phases the decline in SLA was mainly due to reduction in LAI and LAD as compared to dry matter production pre unit assimilatory surface area.

SLA represents relative proportion of mechanical, conductive and assimilatory tissues in leaves. Treatment T<sub>1</sub> (412.34) and T<sub>7</sub> (362.62) possessed the average higher magnitudes for this trait suggesting that the treatment had contributed significantly in enhancing the magnitudes of characters which enhance the photosynthetic efficiency, mobilization efficiency of assimilates from the source to the sink and providing strength to the assimilatory surface area which is beneficial to maintain turgor pressure even under low leaf water potentials.

#### **5.2.2.6 Specific leaf weight (g cm<sup>-2</sup>)**

The present study revealed (Table 13, Fig. 5) that the SLW had a fluctuating trend in most of the treatments with comparatively higher magnitudes during 60-80 DAS. This was attributed to the increase in dry matter production per unit leaf area during later phase of growth. Treatments

T<sub>1</sub> (0.0027) and T<sub>3</sub> (0.0020) recorded an average higher SLW indicating the utility of enhancing per unit leaf area dry matter production efficiency. The fluctuation in SLW during most of the growth period was attributed to the variation in ratio of assimilatory surface area and its per unit dry matter accumulation.

### **5.2.2.7 Biomass duration (g days)**

The treatments varied highly significantly (at 1%) with respect to biomass duration among treatments throughout the growth period (Table 10, Fig. 10).

The present study showed (Table 14, Fig. 6) that the biomass duration had an increasing trend with the enhancement of crop age till 100 DAS, thereafter it had reduction in almost all treatments. The reduction in later growth phase was attributed to the magnitudes of reduced LAI, LAD, CGR and RGR. The biomass duration represents gain and loss of dry matter during successive growth intervals which may be contributing attributes in production of photo-assimilates affecting economic yield.

## **5.3 Other physiological traits and mechanisms:-**

### **5.3.1 Chlorophyll content index**

The grain development was accompanied by decreases in chlorophyll contents of the leaf as a result of ageing (Choudhary et al., 1994). The chlorophyll a/b ratio was correlated with photosynthesis efficiency (Kongjika and Mathis, 1995). The Chlorophyll content was positively correlated with seed yield (Betzelberger et al., 2010). In pea in stem and leaf colour relative chlorophyll contents were approximately 80 and 50%, respectively (Ladygin, 2003). In pea the high temperature and the lack of humidity inhibited the synthesis of chlorophylls a and b (Sakalauskiene et al., 2008).

The present study indicated (Table 15, Fig. 7) that the treatment T<sub>4</sub> (27.24) was found to be associated with the maximum chlorophyll content index indicating the involvement of treatment in accelerating the chlorophyll production by increasing kinetics of pathway leading to the production of chlorophyll. Treatment T<sub>2</sub> (19.59) recorded the minimum. Though the chlorophyll content index does not describe the actual chlorophyll content but still gives an index of chlorophyll content.

### 5.3.2 Quantum efficiency

Quantum yield increased maximum with IAA under field capacity. It decreased with increasing duration of water logging (Pandey et al., 2001). Isoda and Tomagae (2003) observed non significant differences between the treatments in quantum yield of photosystem II (Phi PSII) and non-photochemical quenching (NPQ) except 16 Aug., which are concerning with the efficiency and photoinhibition in PSII, respectively.

The present study indicated (Table 15, Fig. 7) that the treatment T<sub>7</sub> (0.0905) significantly superseded rest of the treatments for quantum efficiency. Treatment T<sub>1</sub> (0.0816) was found to be associated with the lowest magnitude for this trait. The quantum efficiency represents the efficiency of light quantum in converting it into chemical energy which is associated with the photosynthetic productivity.

### 5.3.3 Carboxylation efficiency-( $\mu \text{ mol m}^{-2} \text{ Sec}^{-1}$ ) ( $\mu \text{ mol mol}^{-1}$ )<sup>-1</sup>

The ratio of net photosynthesis rate to intercellular CO<sub>2</sub> concentration is termed as intrinsic carboxylation efficiency, higher ratio better the efficiency for carboxylation (Hamerlynck et al., 2000). The carboxylation efficiency differed significantly among the clones and the clones such as K37, T6, T21 and K4 which had high CE also showed relatively higher WUE (Natraja and Jacob, 1999). The maximal rate of Rubisco carboxylation, generally the limiting photosynthetic process for soybeans, was correlated with photosynthetic capacity (Gilbert et al., 2011). The leaf carbon isotope fractionation with increased Chl levels suggests an enhanced carboxylation capacity in these leaves (Soundararajan et al., 2012).

The present study showed (Table 15, Fig. 7) that the treatments T<sub>2</sub> (223.943) and T<sub>4</sub> (180.85) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>7</sub> (82.793) registered the minimum carboxylation efficiency. The higher magnitudes indicated by the T<sub>2</sub> and T<sub>4</sub> suggested the role of these treatments in increasing the efficiency of Rubisco enzyme responsible for CO<sub>2</sub> assimilation in C<sub>3</sub> plants.

#### **5.3.4 Water use efficiency ( $\mu\text{ mol mmol}^{-1}$ )**

The water use and water use efficiency are critical parameters where water is scarce in pigeonpea crop. The use of less water to achieve high yield is a major object of the modern agriculture (Richards et al., 2001). The higher WUE are often found to maintain lower leaf internal  $\text{CO}_2$  concentration ( $c_i$ ), as estimated by carbon isotope discrimination. However, lower  $c_i$  may result from reduced stomatal conductance, increased mesophyll (non-stomatal) conductance, or a combination of both. When genotypic variation for WUE is found, it may be important for plant breeding purposes to define whether such variation arises from differences in stomatal or non-stomatal restrictions to  $\text{CO}_2$  uptake (Earl, 2002). In pea the large yields in the dry matter production allow greater water use efficiency in the post flowering period Siddique et al., 2001).

The water use efficiency represents the amount of water transpired per unit of  $\text{CO}_2$  assimilated by the photosynthetic surface which was found to be maximum in  $T_7$  (66.39) and  $T_6$  (59.37) in the present study (Table 15, Fig. 7).  $T_1$  (49.50) registered the minimum water use efficiency.

#### **5.3.5 Mesophyll efficiency- $\mu\text{ mol mol}^{-1} (\text{mol m}^{-2} \text{Sec}^{-1})^{-1}$**

At given stomatal conductance, lower  $C_i$  indicated better mesophyll efficiency and better draw down rate of the substrate  $\text{CO}_2$  (Ramanjulu et al., 1998). The yield was positively correlated with mesophyll conductance (Liu et al., 2012).

The present results indicated (Table 15, Fig. 7) that the treatment  $T_1$  (30.17) was found to be associated with the maximum mesophyll efficiency over rest of the treatments which suggested that the Potassium humate provided to the crop through various methods did not have any positive influence on the mesophyll efficiency.  $T_4$  (15.00) recorded the minimum.

#### **2.3.6 Canopy temperature ( $^{\circ}\text{C}$ )**

It had a significant negative correlation with yield, pods per plant and seeds per pod. The temperature regime on pea significantly influenced plant physiological processes (Sakalauskiene et al., 2008). The high temperatures

during the reproductive phase significantly reduced the number of seeds per pod. The photothermal unit received during the vegetative stage had a significant positive correlation with yield, while during the reproductive phase of the crop; it had a significant negative correlation with yield, pods per plant and seeds per pod (Kumar et al., 2006). In pea cultivars with the epicuticular wax content, cuticular transpiration and leaf colour reduce the canopy temperature (Manzanares et al., 1998).

The present study showed (Table 15, Fig. 7) that the treatment T<sub>1</sub> (29.73) and T<sub>2</sub> (28.29) were found to be associated with the highest and lowest magnitudes for this trait.

Canopy temperature is an important trait which is closely linked with the transpiration. Decrease in transpiration rate causes the stomatal closure resulting in increased canopy temperature. The increase in transpiration rate reflects in cooling the canopy results in reduced canopy temperature.

### **5.3.7 Photosynthesis Active Radiation absorption - ( $\mu \text{ mol m}^{-2} \text{ Sec}^{-1}$ )**

The agriculture is basically a system of exploitation of solar radiation through photosynthesis and the amount of intercepted photosynthetic photon flux density (wavelength 400 to 700 nm) has direct relation with leaf area development (Saini et al., 1989). The analysis of crop growth should consider total dry matter (IDM) as a product of the amount of photosynthetically active radiation (PAR) intercepted by the crop multiply by an efficiency factor. Such analysis suggests that reduction utilization efficiency is a conservative quantity (Monteith et al., 1983). The photosynthesis is the corner stone of crop production, it is important to be aware of the energy available to drive photosynthesis process and to know the interception of photosynthetically active radiation at different crop phenological stages in relation to crop growth or biomass production (Jarwal et al., 1990). The variation in productive efficiency between rice cultivars and plant population stress under a given set of environment depends on the rate at which a closed canopy develops leading to better use of incoming solar radiation (Haloi et al., (2000). The relationship between the daily net and gross canopy CO<sub>2</sub> exchange rate and daily absorption of PAR were linear. Higher daily net and gross CO<sub>2</sub> exchange

rates phyto-mass in the narrow spaced canopy were attributed to a greater quantity of daily absorbed PAR through the season, rather than difference in the efficiency of the various canopy structures (Wall and Kanemasu, 2000). The BG362 K850 and Annegiri intercepted higher percentage of photosynthetic active radiation (PAR) compared to the other 3 cultivars in chickpea under both irrigated and unirrigated conditions at the maximum leaf area index (LAI) stage. The intercepted PAR was closely related to biomass production (Lama et al., 2003). The chlorophyll a and b were at minimum level under 100% PAR, which increased with reducing light intensity. At 25% PAR the highest chlorophyll a content was found in P 52 (1.8mg/g). The highest chlorophyll b content was recorded at 25% PAR in all genotypes except genotype IPSA3. At 25% PAR the highest amount of chlorophyll b (Akhter et al., 2005).

The present investigations indicated (Table 15, Fig. 7) that the treatment T<sub>7</sub> (1200.2) recorded the maximum and T<sub>1</sub> (1197.3) the minimum PAR absorption, respectively. The PAR indicates the light wave lengths which are absorbed by the plants efficiently which occurs within the range of 400-700 nm which results in production of ATP required for the reduction of CO<sub>2</sub> in the dark reaction of photosynthesis. Higher PAR absorption is a beneficial trait if the plant cells have the capacity to convert it into the chemical energy efficiently.

### **5.3.8 Net Photosynthesis Rate- ( $\mu \text{ mol m}^{-2} \text{ Sec}^{-1}$ )**

The net photosynthesis rate (pn) is the important factor that determines the biomass production and water use efficiency of a species. Variation in Pn photosynthesis has been reported as determinants of plant productivity (Natraja and Jacob, 1999). The crop yield depends upon both the rate and duration of photosynthesis and increased photosynthesis potential is considered to be a possible approach in improving yield (Ojima et al., 1969). The maximum growth rate of seeds was achieved regardless of the intra-plant competition level and the duration of seed growth was shortened if the photosynthetic activity was not sufficient to fulfil the assimilate demand of filling seeds in grain legumes (Munier-Jolain et al., 1998). The higher productivity of semi dwarf wheat cultivars has been attributed to their greater

leaf photosynthetic rate (Fischer et al., 1998). The photosynthetic activity decreased sharply after 24 h at 45 degrees C (Georgieva et al., 2000). The impact of soil moisture deficit on carbon assimilation was found to be severe even under mild stress due to the damage it causes to the photosynthetic machinery and the photo inhibition due to decreasing leaf turgor Shah et al. (2010). The yield was positively correlated with net photosynthetic rate (Pn). The Pn and Pn/Ci are the effective selection indexes for seed yield and can be used in future breeding programs (Liu et al., 2012). The photosynthetic rate is maximum at the flowering stage and declined at the pod development stage (Kalpana et al., 2003).

The present showed (Table 15, Fig. 7) that the treatments T<sub>7</sub> (108.66) and T<sub>5</sub> (104.2) recorded the higher magnitudes for this trait though they did not differ significantly between them. Treatment T<sub>1</sub> (97.80) registered the minimum. Appeared from the present study that the Potassium humate applied through various methods in garden pea significantly influenced the photosynthetic rate. However, Delfine et al. (2005) reported that the humic acid had limited promoting effects on photosynthetic metabolism of durum wheat crops grown.

#### **5.3.9 Stomatal conductance- ( $\text{mol m}^{-2} \text{Sec}^{-1}$ )**

The stomatal conductance is of utmost importance when photosynthesis is concerned. Stomata play a pivotal role in controlling the balance between assimilation and transpiration (Beadle et al., 1981). The photosynthesis largely depends on stomatal regulation (Hsiao, 1973). The stomatal conductance (SC) and transpiration rate (TR) although possessed significant positive association with photosynthesis rate their associations with grain yield was not significant (Kumar et al., 1998). The drought caused a reduction in stomatal conductance. Reductions in leaf water potential as a consequence of drought positively correlated with a decline in assimilation rate, which was associated with stomatal closure (Anyia and Herzog, 2003). The reduction in transpiration rate and stomatal conductance and concomitant increase in intercellular CO<sub>2</sub> concentration suggests that both stomatal factors were involved in the reduction of photosynthesis (Zhao et al., 2003). The water stress induced decline in PN was accompanied with a significant and

drastic reduction in stomatal conductance. The stomatal conductance by virtue of its effect on movement of carbon dioxide and water vapour across leaf affects transpiration, water balance and photosynthesis throughout the growing period (Burman et al., 2011).

The present investigations showed (Table 15, Fig. 7) that the treatments T<sub>7</sub> (0.099) and T<sub>6</sub> (0.095) recorded the higher magnitudes for this trait. Treatment T<sub>3</sub> (0.042) registered the minimum Stomatal conductance. However, Delfine et al. (2005) did not observe any effect of foliar application of humic acid on stomatal conductance.

The higher stomatal conductance normally favours higher transpiration rate which can be maintained if the plants have the efficiency to compensate the water loss through water absorption. If the transpiration exceeds the absorption this will create the water deficit in the transpiring cells reducing the water content in the transpiring cells resulting in stomatal closure which also causes the reduction in stomatal conductance as well as photosynthetic rate.

#### **5.3.10 Transpiration Rate- ( $\text{m mol m}^{-2} \text{Sec}^{-1}$ )**

The transpiration is one of the major gas exchange parameters associated with plant growth and productivity (Taiz and Zeiger, 2002). It is necessary to have higher plant conductance to achieve higher canopy photosynthesis which would lead to higher canopy photosynthesis and higher biological yield. It should be borne in mind that high plant conductance rate not only enhance the CO<sub>2</sub> exchange rate but also results in higher transpiration rate (Farquhar and Sharkey, 1982). The rate of transpiration decreased with the advancement of maturity. It might have occurred on account of the cumulative effect of decreased soil moisture content (Gupta et al., 2012). In cowpea the transpiration rate is maximum at the flowering stage and declined at the pod development stage (Kalpana et al., 2003).

The present study indicated (Table 15, Fig. 7) that the treatment T<sub>1</sub> (2.220) significantly superseded the rest of the treatments for transpiration rate. Treatment T<sub>7</sub> (1.647) was found to be associated with the lowest magnitude for this trait. It was interesting to observe that the treatment T<sub>7</sub> which recorded the highest stomatal conductance had the minimum

transpiration rate which does not happen normally. In most of the cases higher stomatal conductance rate has been found to be associated with the higher transpiration rate. However, if the plant is unable to meet out its transpirational demands the water scarcity in transpiring cells will cause the stomatal closure which may results in reduced transpiration despite of higher stomal conductance.

#### **5.4 Yields and yield components:-**

##### **5.4.1 Plant height (cm.)**

The poor growth of semi-leafless and tare-leaved types was attributed to increasing shoot height (Armstrong and Patel, 1994). In pea the significant genetic variation was absorbed among the  $F_1$  hybrids for the plant height (Chaudhary and Sharma, 2003 and Pal and Singh, 2012).

The present study showed (Table 16, Fig. 8) that the treatments  $T_1$  (81.87),  $T_6$  (81.74) and  $T_2$  (78.80) recorded the higher magnitudes for this trait though they did not differ significantly among them. Treatment  $T_4$  (73.87) recorded lowest value for this character. The results were in contradictions with the findings of Kumar et al. (2008); Kumar et al. (2014) who noted positive and significant correlation of plant height with the economic productivity. It is further mentioned that highest yielding treatment  $T_5$  possessed an average plant height (77.07) but recorded maximum economic yield.

##### **5.4.2 Number of nodes plant<sup>-1</sup>**

The number of pods plant<sup>-1</sup> had maximum direct genotypic effect on number of nodes per plant; these traits should be for the yield improvement in garden pea plant (Ramesh and Tewatia, 2002). Kosev and Mikic (2012) reported the highest positive indirect effect of number of fertile nodes plant<sup>-1</sup> (12.58) on seed yield in field pea. On the other hand, Armstrong and Patel (1994) reported that the poor growth of semi-leafless and tare-leaved types was attributed to increasing number of nodes plant<sup>-1</sup>.

The present study showed (Table 16, Fig. 8) that the treatment  $T_5$  had the maximum (22.30) nodes plant<sup>-1</sup>. The higher number of nodes increases more chances of pod setting which may results in production of higher number of pods which contributes directly to the economic productivity.  $T_1$  possessed the minimum number of nodes plant<sup>-1</sup> (15.07).

### **5.4.3 Number of pods plant<sup>-1</sup>**

The in pea pods plant<sup>-1</sup> had the greatest direct and indirect effects on green pod yield (Shah and Lal, 1992 and Golaszewski and Puzio-Idzkowska, 1996). The number of pods plant<sup>-1</sup> was highest when each genotype was grown as spaced plants (Moot and McNeil, 1995). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for pods per plant (Singh and Singh, 1996). The phenotypic and genotypic correlations indicated that the number of pods plant<sup>-1</sup> had the greatest direct effects on yield in pigeonpea (Musaana and Nahdy, 1998). The number of pods plant<sup>-1</sup> had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea (Ramesh and Tewatia, 2002).

The results revealed (Table 16, Fig. 8) highly significant differences among treatments for number of pods plant<sup>-1</sup>. The results were in accordance with the findings of Chaudhary and Sharma (2003) in pea and Pal and Singh (2012) in garden pea. Among different treatments T<sub>4</sub> (21.53) and T<sub>5</sub> (21.40) registered higher magnitudes in pod number plant<sup>-1</sup>. The humic acid application @ of 3 kg ha<sup>-1</sup> significantly resulted in higher number of pods plant<sup>-1</sup> in mungbean (Muhammad et al., 2014).

In the present study it has also been recorded that that the higher yield per plant was often due to higher number of pods plant<sup>-1</sup> in treatments as also reported by Gavit et al. (2008) and Guleria et al. (2009). The significant and positive correlation was noted between pods plant<sup>-1</sup> and seed yield (Kumar et al., 2003; Togay et al., 2008; Tripathi et al.; 2011; Kumar et al., 2012 and Kumar et al., 2014).

### **5.4.4 Number of filled pods plant<sup>-1</sup>**

The study indicated (Table 16, Fig. 8) that the treatments T<sub>5</sub> (20.83), T<sub>4</sub> (20.80) and T<sub>7</sub> (18.33) recorded the higher magnitudes for this trait. T<sub>1</sub> (14.27) possessed the minimum.

In the early investigations it has been recorded that number of filled pods play a more crucial role in economic productivity as compared to total number of pods per plant.

#### **5.4.5 Number of empty pods plant<sup>-1</sup>**

The present investigations revealed (Table 16, Fig. 8) that the treatments T<sub>2</sub> and T<sub>3</sub> (0.80) were found to be associated with more number of empty pods per plant, whereas T<sub>1</sub> (0.53), T<sub>6</sub> (0.54) and T<sub>5</sub> (0.57) recorded less number of empty pods per plant. The increase in number of empty pods suggested that either sink is inefficient or translocation of photosynthates to the sink was improper due to increased competition among components of sink.

#### **5.4.6 Number of seeds pod<sup>-1</sup>**

The number of pods per plant had maximum direct genotypic effect on grain weight per pod. These traits should be for the yield improvement in garden pea (Ramesh and Tewatia, 2002). The phenotypic and genotypic correlations showed that the number of seeds pod<sup>-1</sup> had the greatest direct effects on yield in pigeonpea (Musaana and Nahdy, 1998). The seed number pod<sup>-1</sup> was the major yield contributing characters and will help in improving the seed yield in garden pea (Katore and Navale, 2010). In pea seed number plant<sup>-1</sup> showed a significant direct effect on seed yield (Shah and Lal, 1992). The number of seeds per pod was highest when each genotype was grown as spaced plants (Moot and McNeil, 1995). The greater emphasis should be given to characters like number of grains pod<sup>-1</sup> (Kumar and Sharma, 2006). The leaf area plant<sup>-1</sup> had a positive significant association with the number of seeds plant<sup>-1</sup> (0.58) (Udens and Ikpeme, 2012). The highly significant difference was observed in the genotypes for number of seeds pod<sup>-1</sup> in garden pea (Pal and Singh, 2012).

The present study exhibited (Table 16, Fig. 8) that the treatment T<sub>5</sub> (4.51) recorded the maximum and treatment T<sub>1</sub> (3.83) the minimum number of seeds pod<sup>-1</sup>. The higher number of seeds pod<sup>-1</sup> appeared to have contributed remarkably in increasing the economic yield due to its direct involvement as sink component Singh and Malik (1994); Jain kurchavia (2002); Onemi (2003); Kumar et al. (2003); Kumar et al. (2003) and Gavit et al. (2008) too reported similarly.

#### **5.4.7 100 seed weight (g)**

The 100-seed weight was the major yield contributing character and helps in improving the seed yield in garden pea (Katore and Navale, 2010). The 100-seed weight was directly correlated with seed yield  $\text{plot}^{-1}$  (Singh and Malik, 1994). The phenotypic and genotypic correlations indicated that seed weight had the greatest direct effect on yield in pigeonpea (Musaana and Nahdy, 1998). In field pea the direct positive effect on seed yield was found in 100-seed weight (5.92) (Kosev and Mikic, 2012).

The present investigations revealed (Table 16, Fig. 9) that the treatment  $T_5$  recorded the maximum (24.46) 100 seed weight followed by  $T_4$  (24.44) which has directly contributed to the enhancement of economic productivity in garden pea. The results were in accordance with the investigations of Gavit et al. (2008) and Kumar et al. (2014). Humic acid application @ of  $3 \text{ kg ha}^{-1}$  significantly resulted in higher thousand grain weight in mungbean (Muhammad et al., 2014). However, Kamran et al. (2014) reported that the humic acid levels possessed no significant effect on thousand grains weight.

#### **5.4.8 Pod length (cm)**

The pod length was the major yield-contributing character and will help in improving the seed yield in garden pea (Katore and Navale, 2010). In pea pod length showed a significant direct effect on seed yield (Shah and Lal, 1992 and Golaszewski and Puzio-Idzkowska, 1996).

The present study indicated (Table 16, Fig. 8) that the treatment  $T_5$  recorded the maximum pod length (7.81). On the other hand  $T_1$  (6.90) registered the minimum. In the present study the pod length seems to have contributed appreciably in enhancing the economic yield. The number of pods  $\text{plant}^{-1}$  and number of seeds  $\text{pod}^{-1}$  were positively correlated with pod length (Kumar et al., 2003 and Kumar et al., 2014). The pod length showed positive but no significant correlation with yield in pea (Muhammad et al., 2013).

#### **5.4.9 Pod width (mm)**

The pod width showed positive but no significant correlation with yield in pea (Muhammad et al., 2013).

It has been recorded in the present study (Table 16, Fig. 8) that the treatments T<sub>6</sub> (10.86) and T<sub>1</sub> (9.60) were found to be associated with the maximum and minimum pod width, respectively. The higher pod width provides the seeds an opportunity for their expansion.

#### **5.4.10 Pod girth (mm)**

In the present study (Table 16, Fig. 8) it has been noted that the treatment T<sub>6</sub> (3.62) recorded the maximum whereas T<sub>1</sub> (3.20) the minimum pod girth, respectively. Pod girth also provides the seeds more area for their expansion.

#### **5.4.11 Green pod yield (g plant<sup>-1</sup>)**

The greater emphasis should be given to characters like green pod yield per plant (Kumar and Sharma, 2006). The number of pods per plant had maximum direct genotypic effect on days to first picking; these traits should be for the yield improvement in garden pea (Ramesh and Tewatia, 2002). The number of green pods plant<sup>-1</sup> had the highest positive direct effect on green pod yield in pea (Sarnaik et al., 1990). The green pod yield and phenological traits in *Pisum sativum* were highly significant. Green pod yield was influenced by over dominance (Rana and Gupta, 1994). The green pod yield plant<sup>-1</sup> was positively and significantly correlated with number of pods plant<sup>-1</sup>. Days to marketable maturity, plant height, crude protein and days to flower initiation would be more effective for improving green pod yield (Kumar et al., 2008). Pal and Singh (2012) reported the highly significant variation in the genotypes for green pod yield/plant in gardenpea.

The present study indicated (Table 16, Fig. 9) that the treatment T<sub>5</sub> had significant more (105.04) green pod yield as compared to other treatments, followed by T<sub>4</sub> (75.30) which revealed the influence of these treatments in enhancing the market value of garden pea as cash crop. T<sub>1</sub> (59.69) recorded the minimum.

#### 5.4.12 Seed yield (gplant,<sup>-1</sup> kg ha.<sup>-1</sup>)

In pea the seed yield plant<sup>-1</sup> was directly correlated with seed yield plot<sup>-1</sup> (Singh and Malik. 1994). The peas cv. Lincoln and Rondo were sown early (21-22 Oct.), mid-season (4-6 Nov.) or late (18-19 Nov.), the yield was not significantly different between cultivars and was highest with the mid-season sowing date (Alsadon and Khalil, 1994). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for seed yield per plant (Singh and Singh, 1996). In pea cultivars the epicuticular wax content has a beneficial effect on seed yield under rain fed conditions (Manzanares et al., 1998). The higher number of flowers, pods and seeds pod<sup>-1</sup> should be selected to increase the grain yield in pea (Guleria et al., 2009). The positive and significant relationship was noted among seed yield, pods plant<sup>-1</sup> and biological yield in pea (Togay et al., 2008).

The present investigations revealed (Table 16, Fig. 9) that the treatment T<sub>5</sub> (soil application of Potassium humate- 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + soil application of Potassium humate - 4.5@ 5 lit. in 150 lit. of water + after 30 days of first application + foliar spray of Potassium humate - 4.5@ 3 lit. in 150 lit. of water after 45 days of 2<sup>nd</sup> application) outyielded (green pod yield 105.04 g plant<sup>-1</sup>, seed yield 18.31 g plant<sup>-1</sup> and 2038.46 kg ha<sup>-1</sup>) other treatments (75.97 % higher for green pod yield g plant<sup>-1</sup> and 22.77% for seed yield kg/ha over control) owing to the maximum number of nodes plant<sup>-1</sup> (22.30), filled pods plant<sup>-1</sup> (20.83), number of seeds pod<sup>-1</sup> (4.51), 100 seed weight, (24.46 g) and a quite higher number of pods plant<sup>-1</sup> (21.53) reflected in its maximum economic productivity.

Treatment T<sub>4</sub> (soil application of Potassium humate - 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate - 4.5@ 5 lit. in 250 lit. of water after 45 days of 1<sup>st</sup> application) was adjudged as second in yield performance (green pod yield 75.30 g plant<sup>-1</sup>, seed yield 16.79 g plant<sup>-1</sup> and 1987.18 kg ha<sup>-1</sup>). This was attributed to its maximum number of pods plant<sup>-1</sup> (21.53), biological yield (34.22g plant<sup>-1</sup> and 4205.13 kg ha<sup>-1</sup>), and a quite higher number of nodes plant<sup>-1</sup> (21.67), number of filled pods plant<sup>-1</sup> (20.80), number of seeds pod<sup>-1</sup> (4.49), 100 seed weight (24.44g). Control recorded the lowest yield (green pod yield 59.69 g plant<sup>-1</sup>, seed yield

10.53 g plant<sup>-1</sup> and 1660.26 kg ha<sup>-1</sup>) which was attributed to the low performance of almost all yield components.

It appeared from the present investigations that the applications of potassium humate through different methods have improved seed yield in all the treatments over control. The applications of Potassium humate increased the average grain yield from 2.49 to 3.61 ton ha<sup>-1</sup> under normal irrigation scheme in wheat (Shahryari et al., 2009). The increased pea sowing rates increased seed yield (Munakamwe et al., 2012). The humic acid levels significantly increased grain yield ha<sup>-1</sup> (Kamran et al., 2014). On the other hand Delfine et al. (2005) reported that the humic acid had limited promoting effects on plant growth, grain yield and quality of durum wheat crops grown.

#### **5.4.13 Biological yield (gplant,<sup>-1</sup> kgha.<sup>-1</sup>)**

The positive and significant relationship was found among seed yield and pods plant<sup>-1</sup> and biological yield in pea (Togay et al., 2008). The biological yield plant<sup>-1</sup> showed highest and significant association with harvest index (0.628\*) at phenotypic level in garden pea (Sirohi et al., 2006).

The present study revealed (Table 16, Fig. 9) that the treatment T<sub>4</sub> superseded all the treatments for biological yield (34.22 g plant<sup>-1</sup> and 42025.13 Kg ha<sup>-1</sup>) followed by T<sub>5</sub> (29.53 g plant<sup>-1</sup> and 4155.98 Kg ha<sup>-1</sup>). T<sub>3</sub> recorded the minimum (19.90 g plant<sup>-1</sup> and 3352.99 Kg ha<sup>-1</sup>).

The biological yield refers to the total dry mass of plant which is beneficial provided that the allocation of dry matter is more in reproductive sink of the plant. In mungbean the biological yield was not significantly affected by humic acid application methods (Muhammad et al., 2014).

#### **5.4.14 Harvest Index (%)**

The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for harvest index (Singh and Singh, 1996). The epicuticular wax content is associated with turgor pressure maintenance through osmotic adjustment increases harvest index (Manzanares et al., 1998). The water stress conditions reduced the harvest index (69%) (Shadakshari et al., 2014).

The present study revealed (Table 16, Fig. 9) that the treatment T<sub>3</sub> (56.41) recorded the maximum HI followed by T<sub>7</sub> (50.54). The lower economic yield in these treatments despite of higher HI may be attributed to the low mobilization of photo-assimilates to the economic sinks of the plant. T<sub>1</sub> (45.47) recorded the lowest. In chickpea the harvest index and economic yield had significant positive correlation value of ( $r = +0.595$ ), while negative correlation value of ( $r = -0.435$ ) was observed between harvest index and biological yield (Khan et al., 2004). The biological yield per plant showed highest and significant association with harvest index (0.628\*) at phenotypic level in garden pea (Sirohi et al., 2006). In pigeon pea the harvest index had high positive direct effect on seed yield followed by biological yield per plant (Kumar et al., (2013).

## **5.5 Proximate analysis**

### **5.5.1 Protein (%)**

The seed yield showed positive and significant association with protein percentage (0.458\*) (Sirohi et al., 2006). The green pod yield per plant was positively and significantly correlated with crude protein (Kumar et al., 2008). The cropping year had a significant influence on crude protein (Kotlarz et al., 2011).

The proteins have the important role in the plant system for maintaining the structural integrity of cells. In the present study (Table 17, Fig. 10) all the treatments have been found to increase the protein contents over control. The treatment T<sub>5</sub> (20.96) and T<sub>1</sub> (18.20) recorded the maximum and minimum protein contents, respectively. The foliar application with humic acid @ of 2 g L<sup>-1</sup> gave significant increases in protein % as it compared with the control treatment (Habashy et al., 2005). The foliar application with humic acid @2 g L<sup>-1</sup> increased protein% of dry seeds in two growing season (Gad El-Hak, 2012). The large varieties were concentrations of protein 20.75% in DM (Granit) to 31.09% in DM (Sol) (Borowska et al., 1998). The crude protein content (% DM) ranged from 21.5-24.9 in fodder pea varieties and from 21.7-26.3 in edible varieties (Maciejewicz-Rys and Slusarczyk, 2001). The white-flowering peas seeds contained more crude protein (22.03 vs. 20.99%)

(Stanek et al., 2004). The significant varietal variations were noted in the mature dry seeds of pea genotypes of total protein (14.95% to 22.44%) (Guleria et al., 2009). The biochemical analysis of total seed proteins in 8 pea genotypes ranged from 16.3-20.4% with highest protein content (20.4%) exhibited by control Arkel (Gupta and Mahajan, 2010).

### **5.5.2 Carbohydrates (%)**

The carbohydrates are the best source of energy which are utilized for growth and other processes of the plants.

The present study indicated (Table 17, Fig. 10) that the treatment T<sub>1</sub> (43.25) recorded the maximum carbohydrate content over rest of the treatments which revealed the non significant influence of various methods of potassium humate application in garden pea. On the other hand Patil et al. (2013) reported that the potassium humate treated plants showed significant increase in carbohydrate of wheat than control plants (untreated plant). T<sub>7</sub> (42.16) recorded the minimum. The number of pods plant<sup>-1</sup> had maximum direct genotypic effect on total sugars in edible grain (Ramesh and Tewatia, 2002). The large varieties were concentrations of starch 47.13% in DM (Ametyst) to 65.53% in DM (Karat) (Borowska et al., 1998).

### **5.5.3 Fibre (%)**

The fibres are an important constituents of cells which provides the cell mechanical strength and are also associated with the laxative quality of the plant material.

The present study showed (Table 17, Fig. 10) that the treatment T<sub>3</sub> (19.62) possessed the maximum crude fibre, whereas T<sub>5</sub> (18.12) recorded the minimum. Most of the treatments have been reported to increase the crude fibre content in the present study as also reported by Patil et al. (2013). The cropping year had a significant influence on crude fibre (Kotlarz et al., 2011). The large varieties were concentrations of fibre 6.47% in DM (Agat) to 26.14% in DM (Rubin) (Borowska et al., 1998). The white-flowering peas seeds contained less neutral detergent fibre (NDF) (18.72 vs. 20.54%) (Stanek et al., 2004).

#### **5.5.4 Fat (%)**

The fats are important constituents of plants and serve as energy source when hydrolysed.

The present study showed (Table 17, Fig. 10) that most of the treatments were found to enhance the fat contents in garden pea. The treatment T<sub>4</sub> (5.78) significantly superseded rest of the treatments for fat (%). T<sub>7</sub> (4.27) was found to be associated with the lowest magnitude for this trait. The foliar and soil application of humic acid significantly improved oil content of mustard (Chris et al., 2005). The cropping year had a significant influence on crude oil (Kotlarz et al., 2011).

#### **5.5.5 Ash (%)**

The ash content indirectly represents the content of inorganic salts of the plant which can only be analysed after drying the plant samples to vary higher temperatures of around 700 °C in a muffle furnace for its conversion into ash.

The present study indicated (Table 17, Fig. 10) that the treatment T<sub>7</sub> (3.98) and T<sub>6</sub> (3.74) were found to be associated with the higher magnitudes for this character. Treatment T<sub>4</sub> (2.12) registered the minimum ash content. The application of potassium humate by various methods in the present study does not seemed to influence the ash content. The cropping year had a significant influence on crude ash (Kotlarz et al., (2011).

## SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

### 6.1 Summary

The present research experiment entitled "Morpho-physiological traits and productivity in garden pea (*Pisum sativum* L.) as influenced by various methods of Potassium humate 4.5 application" was conducted at the Experimental area, Department of Plant Physiology, JNKVV, Jabalpur ( M.P.) during Rabi season of 2014-15. The research experiment was laid out in a randomized block design replicated thrice and treatments comprised of seven various methods of Potassium humate application in garden pea crop viz; T<sub>1</sub> (Only normal package of practices without application of Potassium humate (control), T<sub>2</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after one month of first application), T<sub>3</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/fertilizer + Second soil application 5liter/with150 liter of water one month of the first application), T<sub>4</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after 45 days of first application), T<sub>5</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/fertilizer + soil application of Potassium humate 4.5@ 5 liter in 150 liter of water + after 30 days of first application + foliar spray of Potassium humate 4.5@ 3 liter in 150 liter of water after 45 days of second application), T<sub>6</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water immediately after first picking) and T<sub>7</sub> (Soil application of Potassium humate 4.5@ 5 liter/acre before the basal dose of manure/Fertilizer + foliar spray of Potassium humate 4.5@ 5 liter in 250 liter of water after 15 days of first picking).

The phenological changes were recorded through visual observations. The sampling to analyze the dry matter production and partitioning efficiencies and growth analytical parameters viz; LAI, LAD, CGR, RGR, SLA, SLW and BMD among treatments was carried out from 20 days after sowing (DAS) onwards at 20 days intervals till maturity. The observations were recorded on plant height (cm), number of nodes plant<sup>-1</sup>, number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup>, number of filled pods plant<sup>-1</sup>, number of empty pods plant<sup>-1</sup>, 100 seeds weight (g), pod length (cm.), pod width (mm.) pod girth (mm.), green pod yield (g plant<sup>-1</sup>), seed yield (g plant<sup>-1</sup> kg ha<sup>-1</sup>), biological yield (g plant<sup>-1</sup> kg ha<sup>-1</sup>) and harvest index (%). The proximate analysis on protein, carbohydrate, fiber, fat and ash contents of seeds was done at maturity.

The physiological traits and mechanisms Viz; quantum efficiency, carboxylation efficiency, water use efficiency, mesophyll efficiency, canopy temperature, photosynthesis active radiation absorption, net photosynthetic rate, stomatal conductance and transpiration rate were measured by using infrared gas analyzer (IRGA), whereas chlorophyll content index was quantified by using chlorophyll meter (Model CCM 200).

Study of phenological traits indicated that the treatment T<sub>2</sub> (76.66 days) was found to be associated with the longest reproductive period, whereas T<sub>5</sub> (74.66 days) recorded a quite less time for this period. On the other hand T<sub>4</sub> (61.66 days) had the longest seed filling period, whereas, T<sub>5</sub> (60.00 days) recorded the minimum time for seed filling. Treatment T<sub>1</sub> (37.34 days) had the longest vegetative phase and T<sub>7</sub> (33.66 days) shortest.

The dry matter accumulation in leaves had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined. Treatments T<sub>6</sub> (2.18 g) and T<sub>2</sub> (2.11 g) were associated with an average higher DM production in leaves.

Dry matter accumulation in stem had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it had a fluctuating trend till maturity. Treatment T<sub>5</sub> (2.71 g) and T<sub>7</sub> (2.70 g) exhibited relatively high stem dry weight over to other treatments.

Dry matter accumulation in tendril had a continuous increase with the advancement of crop growth and after attaining the peak at 80 DAS it declined. Treatments T<sub>4</sub> (0.27 g) and T<sub>7</sub> (0.23 g) were associated with an average higher DM production in tendril.

Dry matter accumulation in pods was found to increase with the advancement of crop growth till maturity in all treatments. Maximum dry matter production in pods were achieved in treatment T<sub>5</sub> (11.21 g) followed by T<sub>4</sub> (10.46 g).

TDM accumulation had a continuous increase with advancement of crop age till maturity in most of the treatments except in T<sub>6</sub> it was reduced at harvest. Treatments T<sub>5</sub> (12.36) and T<sub>4</sub> (11.48) had average higher TDM production (g plant<sup>-1</sup>), respectively.

Among growth analytical parameters the LAI had increased with the advancement of crop growth with the peak attained at 80 DAS, thereafter it reduced in all the treatments. Treatments T<sub>1</sub> (2.93) and T<sub>7</sub> (2.92) had an average higher LAI.

LAD had an increasing trend with the enhancement of crop age till 80 DAS, thereafter it had a reduction in almost all treatments except in T<sub>2</sub> it had a marginal increase. T<sub>4</sub> (16251.84) and T<sub>6</sub> (14124.54) possessed relatively higher magnitudes for this character over others.

CGR had an increasing trend with the enhancement of crop age till 100 DAS, thereafter it had reduction in almost all treatments except in T<sub>2</sub> and T<sub>3</sub> it had a continuous increase till harvest. The average highest CGR was recorded in T<sub>5</sub> (0.00109) followed by T<sub>2</sub> (0.00094).

RGR possessed the maximum magnitudes in the early growth phase followed by a subsequent decline in remaining span of growth in all the treatments. T<sub>5</sub> (0.051) registered the average highest values for this trait followed by T<sub>4</sub> (0.050).

SLA had a fluctuating trend during the life span of garden pea in different treatments with comparatively higher and lower values attained during early and later growth span of crop, respectively. The average highest was recorded in T<sub>1</sub> (412.34) and followed by T<sub>7</sub> (362.62).

SLW had a fluctuating trend in most of the treatments with comparatively higher magnitudes during 60-80 DAS. Treatments T<sub>1</sub> exhibited an average highest SLW (0.0027) followed by T<sub>3</sub> (0.0020).

The biomass duration had an increasing trend with the enhancement of crop age till 100 DAS, thereafter it had a reduction in almost all treatments. T<sub>4</sub> (177.17) and T<sub>5</sub> (175.92) possessed relatively higher magnitudes for this character over others.

Quantification of various other physiological traits and mechanisms indicated that the Treatment T<sub>4</sub> (27.24) possessed the higher chlorophyll content index and minimum was recorded in treatment T<sub>3</sub> (19.59). Maximum quantum efficiency was noted in treatments T<sub>7</sub> (0.0905), followed by T<sub>1</sub> (0.0816). Maximum carboxylation efficiency was noted in treatment T<sub>2</sub> (223.943  $\mu\text{mol}/\text{m}^2/\text{s}^{-1}$  ( $\mu\text{mol mmol}^{-1}$ )<sup>-1</sup>), net photosynthetic rate in T<sub>7</sub> (108.66  $\mu\text{mol}/\text{m}^2/\text{s}$ ) followed by T<sub>1</sub> (97.80  $\mu\text{mol}/\text{m}^2/\text{s}$ ), water use efficiency in T<sub>7</sub> (66.39  $\mu\text{mol}/\text{mmol}$ ) followed by T<sub>1</sub> (49.50  $\mu\text{mol}/\text{mmol}$ ), stomatal conductance in T<sub>7</sub> (0.099  $\text{mol}/\text{m}^2/\text{s}$ ) followed by T<sub>3</sub> (0.042  $\text{mol}/\text{m}^2/\text{s}$ ), canopy temperature (29.73°C), transpiration rate (2.220  $\text{mmol}/\text{m}^2/\text{s}$ ) and mesophyll efficiency in T<sub>1</sub> (30.17  $\mu\text{mol mol}^{-1}(\text{mol m}^{-2}\text{s}^{-1})^{-1}$ ) followed by T<sub>4</sub> (15.00  $\mu\text{mol mol}^{-1}(\text{mol m}^{-2}\text{s}^{-1})^{-1}$ ) and PAR absorption in T<sub>7</sub> (1200.2 ( $\mu\text{ mol m}^{-2}\text{ Sec}^{-1}$ )) followed by T<sub>1</sub> (1100.3 ( $\mu\text{ mol m}^{-2}\text{ Sec}^{-1}$ )).

Among yield and yield components the treatment T<sub>5</sub> outyielded (green pod yield 105.04 g plant<sup>-1</sup>, seed yield 18.31 g plant<sup>-1</sup> and 2038.46 kg ha<sup>-1</sup>) other treatments (75.97% higher for green pod yield g plant<sup>-1</sup> and 22.77 % for seed yield kg ha<sup>-1</sup> over control) owing to the maximum number of nodes plant<sup>-1</sup> (22.30), filled pods plant<sup>-1</sup> (20.83), number of seeds pod<sup>-1</sup> (4.51), 100 seed weight, (24.46 g) and a quite higher number of pods plant<sup>-1</sup> (21.53) reflected in its maximum economic productivity.

Treatment T<sub>4</sub> was adjudged as second in yield performance (green pod yield 75.30 g plant<sup>-1</sup>, seed yield 16.79 g plant<sup>-1</sup> and 1987.18 kg ha<sup>-1</sup>). This was attributed to its maximum number of pods plant<sup>-1</sup> (21.53), biological yield (34.22 g plant<sup>-1</sup> and 4205.13 kg ha<sup>-1</sup>) and a quite higher number of nodes plant<sup>-1</sup> (21.67), number of filled pods plant<sup>-1</sup> (20.80), number of seeds pod<sup>-1</sup> (4.49), 100 seed weight (24.44 g). Control recorded the lowest yield (green

pod yield 59.69 g plant<sup>-1</sup>, seed yield 10.53 g plant<sup>-1</sup> and 1660.26 kg ha<sup>-1</sup>) which was attributed to the low performance of almost all yield components.

The quantification of seed quality characteristics indicated variable response. In proximate analysis the maximum protein content was registered in treatments T<sub>5</sub> (20.96%) followed by T<sub>1</sub> (18.20%). Maximum carbohydrate (%) was registered in Treatments T<sub>1</sub> (43.25) and minimum in T<sub>7</sub> (42.16). Fat (%) was found to be maximum in Treatment T<sub>4</sub> (5.78). Maximum fiber (%) was noted in Treatments T<sub>3</sub> (19.62) followed by T<sub>5</sub> (18.12). Significantly maximum ash (%) was registered in treatment T<sub>7</sub> (3.98).

## 6.2 Conclusions

### The results revealed that following

1. Amongst different treatments T<sub>2</sub> was found to be associated with the longest reproductive period (76.66 days), whereas T<sub>5</sub> (74.66 days) recorded a quite less time for this period. On the other hand T<sub>4</sub> (61.66 days) had the longest seed filling period, whereas T<sub>5</sub> (60.00 days) recorded the minimum time for seed filling. Treatment T<sub>1</sub> (37.34 days) had the longest vegetative phase and T<sub>7</sub> (33.66 days) shortest which clearly revealed influence of various treatments of Potassium humate on phenophases in garden pea.
2. Treatment T<sub>6</sub> possessed an average maximum dry matter production (2.18 g plant<sup>-1</sup>) in leaves and stem (2.71 g plant<sup>-1</sup>), T<sub>4</sub> in tendril (0.27 g plant<sup>-1</sup>), T<sub>5</sub> in pods (11.21 g plant<sup>-1</sup>) as well as total (12.36 g plant<sup>-1</sup>). Average higher LAI was noted in T<sub>1</sub> (2.93), LAD (16251.84 cm<sup>2</sup> days), CGR (0.00109 g/cm<sup>2</sup>/day) in T<sub>4</sub> and RGR in T<sub>5</sub> (0.051 g cm<sup>-2</sup>) which apparently showed the impact of various treatments of Potassium humate on growth analytical traits.
3. Leaves of treatment T<sub>7</sub> exhibited maximum chlorophyll value (SPAD value 27.24), quantum efficiency (0.905), water use efficiency (66.393 μmol/mmol), net photosynthetic rate (108.663 μmol/m<sup>2</sup>/s<sup>-1</sup>), stomatal conductance (0.099 mol/m<sup>2</sup>/s), PAR absorption (1200.20 μ mol m<sup>-2</sup> Sec<sup>-1</sup>), T<sub>2</sub> carboxylation efficiency (223.943 μmolm<sup>-2</sup>s<sup>-1</sup> (μmolmol<sup>-1</sup>) and T<sub>1</sub> mesophyll efficiency (30.170 μmol mol<sup>-1</sup>(mol m<sup>-2</sup>s<sup>-1</sup>)<sup>-1</sup>, canopy temperature (29.730<sup>0</sup>c) and transpiration rate (2.220 mmol/m<sup>2</sup>/s), respectively.

4. The treatment T<sub>5</sub> (Soil application of Potassium humate- 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + Soil application of Potassium humate - 4.5@ 5 lit. in 150 lit. of water + after 30 days of first application + foliar spray of Potassium humate - 4.5@ 3 lit. in 150 lit. of water after 45 days of 2<sup>nd</sup> application) outyielded (green pod yield 105.04 g plant<sup>-1</sup>, seed yield 18.31 g plant<sup>-1</sup> and 2038.46 kg ha<sup>-1</sup>) other treatments (75.97 % higher for green pod yield g plant<sup>-1</sup> and 22.77 % for seed yield kg ha<sup>-1</sup> over control) owing to the maximum number of nodes plant<sup>-1</sup> (22.30), filled pods plant<sup>-1</sup> (20.83), number of seeds pod<sup>-1</sup> (4.51), 100 seed weight, (24.46 g) and a quite higher number of pods plant<sup>-1</sup> (21.53) reflected in its maximum economic productivity.

Treatment T<sub>4</sub> (Soil application of Potassium humate - 4.5@ 5 lit./acre before the basal dose of manure/fertilizer + foliar spray of Potassium humate - 4.5@ 5 lit. in 250 lit. of water after 45 days of 1<sup>st</sup> application) was adjudged as second in yield performance (green pod yield 75.30 g plant<sup>-1</sup>, seed yield 16.79 g plant<sup>-1</sup> and 1987.18 kg ha<sup>-1</sup>). Control recorded the lowest yield (green pod yield 59.69 g plant<sup>-1</sup>, seed yield 10.53 g plant<sup>-1</sup> and 1660.26 kg ha<sup>-1</sup>) which was attributed to the low performance of almost all yield components.

5. The proximate analysis indicated variable response. T<sub>5</sub> registered the maximum protein (20.96 %), T<sub>1</sub> carbohydrate (43.25 %), T<sub>4</sub> (5.78 %) fat, T<sub>3</sub> fibre (19.62 %) and T<sub>7</sub> (3.98 %) ash contents, respectively.

### **6.3 Suggestions for further work**

- (1) The results are required to be conducted on different agroclimatic zones of India for authentication of results.
- (2) The investigations are proposed to be recorded on more number of genotypes of garden pea.
- (3) The investigation should involve more number of crops with some more methods of applications to provide a wide range of recommendations.
- (4) More number of morphophysiological parameters be incorporated in the study covering the molecular aspects.

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## APPENDICES

**Various phenophases of garden pea under various treatments during crop growth period**

**(A)**

Source of variance	d.f	Days to seedling emergence	Days to 2 to 4 leaf stage	Days to tendrill formation	Days to 1 <sup>st</sup> flower initiation	Days to 50 % flowering
Replication	2	0.317	1.444	1.444	2.63	4.43
Treatment	6	0.048	0.190	0.190	1.29	0.19
Error	12	0.270	0.468	0.468	0.40	0.36

**(B)**

Source of variance	d.f	Days to pod initiation	Days to seed formation	Days to 1 <sup>st</sup> picking	Days to Physiological maturity	Days to physical maturity
Replication	2	3.65	6.984	52.302	16.825	12.429
Treatment	6	0.90	1.286	7.429	1.333	1.000
Error	12	0.46	1.675	3.040	1.611	1.500

**DM accumulation (g plant<sup>-1</sup>) in leaves during successive growth period in various treatments**

Source of variance	d.f	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.00060	0.058	0.390	1.338	0.153	0.138
Treatment	6	0.00016	0.026	0.258	0.175	0.027	0.010
Error	12	0.00012	0.010	0.082	0.268	0.020	0.020

**DM accumulation (g plant<sup>-1</sup>) in main stem in garden pea during successive growth period in various treatments**

Source of variance	d.f	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.00012	0.05455	0.40022	0.95457	0.40686	0.43565
Treatment	6	0.00005	0.00086	0.01428	0.38554	0.11379	0.09362
Error	12	0.00009	0.00710	0.05140	0.12455	0.09976	0.05729

**DM accumulation (g plant<sup>-1</sup>) in tendrils during successive growth period in various treatments**

Source of variance	d.f	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.00000001	0.0011	0.0054	0.0135	0.0063	0.00528
Treatment	6	0.00000000	0.0006	0.0055	0.0020	0.0002	0.00002
Error	12	0.00000001	0.0002	0.0017	0.0013	0.0011	0.00055

**DM accumulation (g plant<sup>-1</sup>) in pods in garden pea at successive growth intervals**

Source of variance	d.f	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.12455	14.89872	18.47580	22.72071
Treatment	6	0.00463	1.65321	4.47431	10.32417
Error	12	0.02051	1.12880	1.25846	2.70873

**TDM accumulation (g plant<sup>-1</sup>) in garden pea at successive growth intervals in various treatments**

Source of variance	d.f	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.00090	0.24566	1.74228	32.50411	23.66590	29.76981
Treatment	6	0.00004	0.04261	0.52848	1.17232	1.84852	10.03555
Error	12	0.00014	0.01588	0.15810	1.21220	0.79266	2.89620

**Leaf area index (LAI) in garden pea during successive growth intervals in different treatments**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS
Replication	2	0.06	0.11	0.27	0.65
Treatment	6	0.02	0.03	0.03	0.43
Error	12	0.01	0.01	0.03	0.19

**Leaf area duration (LAD) (cm<sup>2</sup>.day) of garden pea during successive growth Intervals in various treatments**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS
Replication	2	2499860.47	12249810.14	66309810.55	65897855.02
Treatment	6	2276.18	1267221.13	114327.13	21031.75
Error	12	25381.42	925099.16	1952007.51	2839403.41

**Crop growth rate (g cm<sup>-2</sup> day<sup>-1</sup>) of garden pea during crop life span in various treatments**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.000000006	0.000000028	0.00000006	0.00000048	0.00000045
Treatment	6	0.000000001	0.000000001	0.00000001	0.00000003	0.00000003
Error	12	0.000000001	0.000000004	0.00000002	0.00000007	0.00000003

**Relative growth rate (g g<sup>-1</sup> day<sup>-1</sup>) of garden pea during crop life span in different treatments.**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	0.00022	0.0002898	0.000055	0.000121	0.000100
Treatment	6	0.00002	0.0000005	0.000010	0.000012	0.000006
Error	12	0.00003	0.0000257	0.000005	0.000012	0.000008

**Specific leaf area (cm<sup>2</sup>g<sup>-1</sup>) of garden pea during crop life span in different treatments**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS
Replication	2	7527.01	8117.07	5865.10	9125.30
Treatment	6	577.17	2336.25	28.95	919.21
Error	12	974.63	1533.52	1140.78	1292.11

**Specific leaf weight (g cm<sup>-2</sup>) of garden pea during crop life span in different treatments.**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS
Replication	2	0.00000039	0.00000039	0.00000006	0.00000028
Treatment	6	0.00000004	0.00000008	0.00000000	0.00000005
Error	12	0.00000003	0.00000002	0.00000001	0.00000006

**Biomass duration (g days) of garden pea during crop life span in various treatments**

Source of variance	d.f	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Replication	2	7.495	118.93	862.349	2686.116	2448.20
Treatment	6	0.660	22.39	253.440	206.131	161.45
Error	12	0.718	6.28	92.526	247.120	42.16

**Quantification of physiological traits and mechanisms in different treatments**

Source of variance	d.f	Chlorophyll content index	Quantum efficiency	Carboxylation efficiency	WUE	Mesophyll Efficiency	Canopy Temp.
Replication	2	20.566	0.000021	7571.312	79.409	83.200	0.85
Treatment	6	1.888	0.000006	2191.001	57.699	3.166	0.31
Error	12	1.302	0.000003	1018.567	17.194	10.986	0.17

Source of variance	d.f	Photosynthesis Active Radiation absorption	Net Photosynthesis Rate	Stomatal conductance	Transpiration Rate
Replication	2	2.804	31.679	0.002	0.05
Treatment	6	0.220	13.967	0.000	0.02
Error	12	0.471	8.743	0.000	0.01

### Biochemical constituents of garden pea in various treatments

Source of variance	d.f	Protein%	Carbohydrate%	Fibre (%)	Fat%	Ash %
Replication	2	2.98	0.49	1.02	0.81	1.07
Treatment	6	0.18	0.05	0.16	0.16	0.06
Error	12	0.05	0.06	0.05	0.13	0.02

### Yield and yield contributing attributes in different treatments in garden pea

(A)

Source of variance	d.f	Plant height (cm.)	No. of nodes plant <sup>-1</sup>	No. of pods plant <sup>-1</sup>	No. of filled pods plant <sup>-1</sup>	No. of empty pods plant <sup>-1</sup>
Replication	2	28.335	27.405	23.19	23.10	0.032
Treatment	6	2.006	6.464	1.26	0.87	0.005
Error	12	4.499	3.161	2.60	2.86	0.013

(B)

Source of variance	d.f	No. of seeds pod <sup>-1</sup>	100 seeds weight (g)	Pod length (cm)	Pod width (mm)	Pod girth (mm)
Replication	2	0.163	0.40	0.255	0.656	0.45
Treatment	6	0.007	0.11	0.047	0.068	0.68
Error	12	0.018	0.15	0.034	0.088	0.29

(C)

Source of variance	d.f	Green pod yield (g plant <sup>-1</sup> )	Seed yield		Biological yield		Harvest index (%)
			g plant <sup>-1</sup>	Kg ha <sup>-1</sup>	g plant <sup>-1</sup>	Kg ha <sup>-1</sup>	
Replication	2	708.723	22.738	50178.506	66.39	256024.337	37.50
Treatment	6	75.668	0.887	9428.161	20.94	1731.376	10.31
Error	12	27.881	2.122	3971.799	6.57	46156.416	11.30

