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Effect of water soluble fertilizers on growth parameters of bush pepper (*Piper nigrum* L.) under Konkan agro-climatic conditions of Maharashtra

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Abstract
The present investigation entitled "effect of soluble fertilizers on growth of bush pepper (*Piper nigrum* L.)" was carried out at College of Horticulture, Dapoli. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra) during 2020-21 and 2021- 2022. The experiment was laid out in randomized block design with seven treatments and four replications. At 720 days after planting treatment T_5 i.e. application of 125 per cent RDF through WSF at weekly interval recorded maximum plant height (102.30cm), number of new shoots per plant (9.01), number of primary and secondary branches per plant (7.23 and 3.78, respectively), number of leaves per branch (7.43), average leaf area (121.62cm^2), plant girth (2.82cm), shoot to root ration on dry weight basis (28.87) and relative growth rate (2.01cm/cm/day).

Keywords: *Piper nigrum* L., soluble fertilizers, agro-climatic

Introduction
Black pepper is the ethno medicine of many countries for its multi-dimensional medicinal properties (Scott *et al*., 2008) [36]. From all spices pepper alone contributes about 70 per cent of total export earnings. Because of its unique position in the international trade it is popularly known as "Black gold" Black Pepper is regained as a paramount spice for several centuries (Devasahayam *et al.*, 2006) [6]. India ranked in the top most position in the world's pepper production until 19th century, but later India lost its position to some other nations like Vietnam and Indonesia (Abraham, 2018) [1]. Presently, the leading countries in the production of the Black Pepper are Vietnam, Indonesia, India and Brazil (Patil*et al.*, 2016) [29]. The area and production of Black Pepper is 3,09,335 ha. and 65,000 tones respectively in India (Anonymous, 2022) [4]. In India, Kerala and Karnataka are the largest producer states and account about over 50 per cent of India's total production. USA, UK, Germany, Vietnam, Netherlands, Japan and Sweden are the major buyers of black pepper from India (Abraham, 2018) [1]. High yield of bush pepper is urgently needed to meet the increasing population and growing demand for food. One of the main problems faced by the pepper farmers is the high cost of production due to increasing trend of using inorganic fertilizers. The problem is complex because black pepper is a high nutrient demanding crop. Bush Pepper is a surface feeder crop and as it yields throughout the year. Further its nutrient scheduling is the most important aspect to gain higher yields. The evaluation of nutrient uptake from soil and partitioning can provide the foundation for fine tuning nutrient management practices as producers aim for increased yield and profitability. Keeping in view this experiment was conducted to study effect of water soluble fertilizers on growth parameters of bush pepper.

Material and Methods
The experiment was conducted at College of Horticulture, Dapoli, Dist. Ratnagiri (MS) during the year 2020-21 and 2021-22. The healthy, pest and disease free three months old rooted cuttings of variety 'Panniyur-1' planted in polybags were used for planting for this experiment. The three grades of water-soluble fertilizers like urea, 19:19:19 and 00:00:50 were used. The recommended dose of straight fertilizers like urea, single super phosphate and muriate of potash were used as control. Bush pepper is small bush grown either in field or pots with yield of 300-500g per plant per year.

A fertilizer dose of 25:10:35g NPK per plant per year was considered as recommended dose i.e. ¼ of the vine black pepper plant. From treatment T_1 to T_6 water soluble fertilizers were applied by drenching 100 ml solution to each plant at weekly interval. Total 52 drenching were done in each year. For treatment T_7 recommended fertilizers were applied in August and January months. All the treatments were supplied with FYM @ 5kg/bush/year + *Trichoderma harzianum* @ 50g / bush/ year (Devasahayam *et al.*, 2015) [7] in equal split doses twice in a year. The field experiment was laid out in a randomized block design (RBD) comprising of seven treatments with four replications i.e., T_1 -25% of the RDF through soluble fertilizers at weekly interval,T_2-50% of the RDF through soluble fertilizers at weekly interval T_3-75% of the RDF through soluble fertilizers at weekly interval,T_4-100% of the RDF through soluble fertilizers at weekly interval, T_5-125% of the recommended dose of fertilizer through soluble fertilizers at weekly interval, T_6-150% of the RDF through soluble fertilizers at weekly interval, T_7- Control - 100% of the RDF through straight fertilizers in two equal split doses in a year. (25:10:35g NPK per plant per year).

Though bush pepper is a perennial crop the observations about growth parameters namely plant height (cm), number of new shoots/plant, number of primary and secondary branches, number of leaves per branch, leaf area (cm^2), plant girth (cm), Root to shoot ratio at harvestwere recorded as per the methodology given below.

To measure the plant height, Number of new shoots per plant, number of primary and secondary branches 5 plants of bush pepper was randomly selected from each treatment and replication. The plant height was measured by using flexible measuring scale from soil surface to the growing point of plant at the interval of 90 days and mean was expressed in centimeter whereas, number of new sprouted shoots and primary and secondary branches were counted at 90 days interval after planting and observations are presented in Table 1.

Table 1: Effect of soluble fertilizers on growth parameters of bush pepper at 720 days after planting

Treatments	Plant height (cm)	Number of new shoots/plant	Number of primary branches/ plant	Number of secondary branches/plant	Number of leaves/ branch	Leaf area (cm^2)	Plant girth (cm)	Root to shoot ratio on dry weight basis
T_1	58.53	6.08	5.08	3.00	5.05	72.06	1.96	21.29
T_2	70.48	7.18	6.05	3.28	5.40	77.42	2.28	23.83
T_3	75.35	7.85	6.45	3.35	6.00	87.11	2.54	24.45
T_4	80.23	8.25	6.80	3.45	6.25	106.66	2.71	25.43
T_5	102.30	9.01	7.23	3.78	7.43	121.62	2.82	28.87
T_6	70.68	6.55	6.63	3.45	5.45	93.61	2.19	23.06
T_7	64.45	5.56	5.23	3.33	4.15	84.22	2.17	22.14
S.Em±	0.46	0.22	0.29	0.14	0.19	1.86	0.13	-
CD at 5%	1.34	0.62	0.83	0.39	0.54	5.39	0.39	-

T_1	25% of RDF	T_2	50% of RDF	T_3	75% of RDF
T_4	100% of RDF	T_5	125% of RDF	T_6	150% of RDF
T_7	Control-(100% RDF) 25:10:35 g NPK/bush/year applied through straight fertilizer intwo equal split doses in a year (August and January)				

DAP – Days after planting, RDF – Recommended dose of fertilizer

To count the number of leaves per branch just initiated new branch were selected and tagged from each treatment and replication. The number of leaves per branch was counted and observations were recorded at 90 days interval after planting. At 360 and 720 days after planting 5 leaves of varying size were collected randomly from each treatment and leaf area was determined with the help of digital leaf area meter available at Department of Agronomy, College of Agriculture, Dapoli. The average of leaf area of five leaves was calculated for statistical analysis and mean was expressed in cm^2. To measure plant girth five plants of bush pepper were selected and tagged from each treatment and replication. The plant girth was measured with the help of vernier caliper at collar region of plant at 90 days interval and observations were recorded and expressed in centimeter.

After harvesting shoot root ratio on dry weight basis was calculated by using the formula

$$\text{Shoot Root weight ratio} = \frac{\text{Total dry weight of shoot (g)}}{\text{Total dry weight of root (g)}}$$

The data pertaining to number of leaves, leaf area and plant girth and shoot root ratio on dry weight basis is presented in Table 1.

RGR for increase in plant height was calculated by using the formula

$$\text{RGR} = \frac{\ln(H_2 - H_1)}{t_2 - t_1}$$

Where,H_1 – Height at time one, H_2 – height at time two, t_1 – time one, t_2 – time two, ln – natural logarithm. The observations related to relative growth rate was presented in Table 2 and depicted in Fig. 1.

Table 2: Effect of soluble fertilizers on relative growth rate (cm/cm/day) for plant height in bush pepper

Treatments	Relative growth rate (cm/cm/day)							
	0-90 DAP	90-180 DAP	180-270 DAP	270-360 DAP	360- 450 DAP	450-540 DAP	540-630 DAP	630-720 DAP
T_1	1.422	1.483	1.552	1.585	1.674	1.711	1.744	1.767
T_2	1.511	1.584	1.655	1.690	1.715	1.781	1.809	1.848
T_3	1.523	1.627	1.684	1.708	1.739	1.815	1.841	1.877
T_4	1.550	1.646	1.704	1.727	1.766	1.837	1.870	1.904
T_5	1.593	1.696	1.766	1.796	1.834	1.904	1.941	2.010
T_6	1.479	1.608	1.673	1.704	1.743	1.797	1.824	1.849
T_7	1.470	1.550	1.587	1.613	1.657	1.737	1.767	1.809
SEm±	0.049	0.081	0.041	0.043	0.073	0.036	0.042	0.044
CD at 5%	0.142	0.236	0.120	0.124	0.212	0.105	0.121	0.128

T_1	25% of RDF	T_2	50% of RDF	T_3	75% of RDF
T_4	100% of RDF	T_5	125% of RDF	T_6	150% of RDF
T_7	Control-(100% RDF) 25:10:35 g NPK/bush/year applied through straight fertilizer intwo equal split doses in a year (August and January)				

DAP – Days after planting RDF – Recommended dose of fertilizer

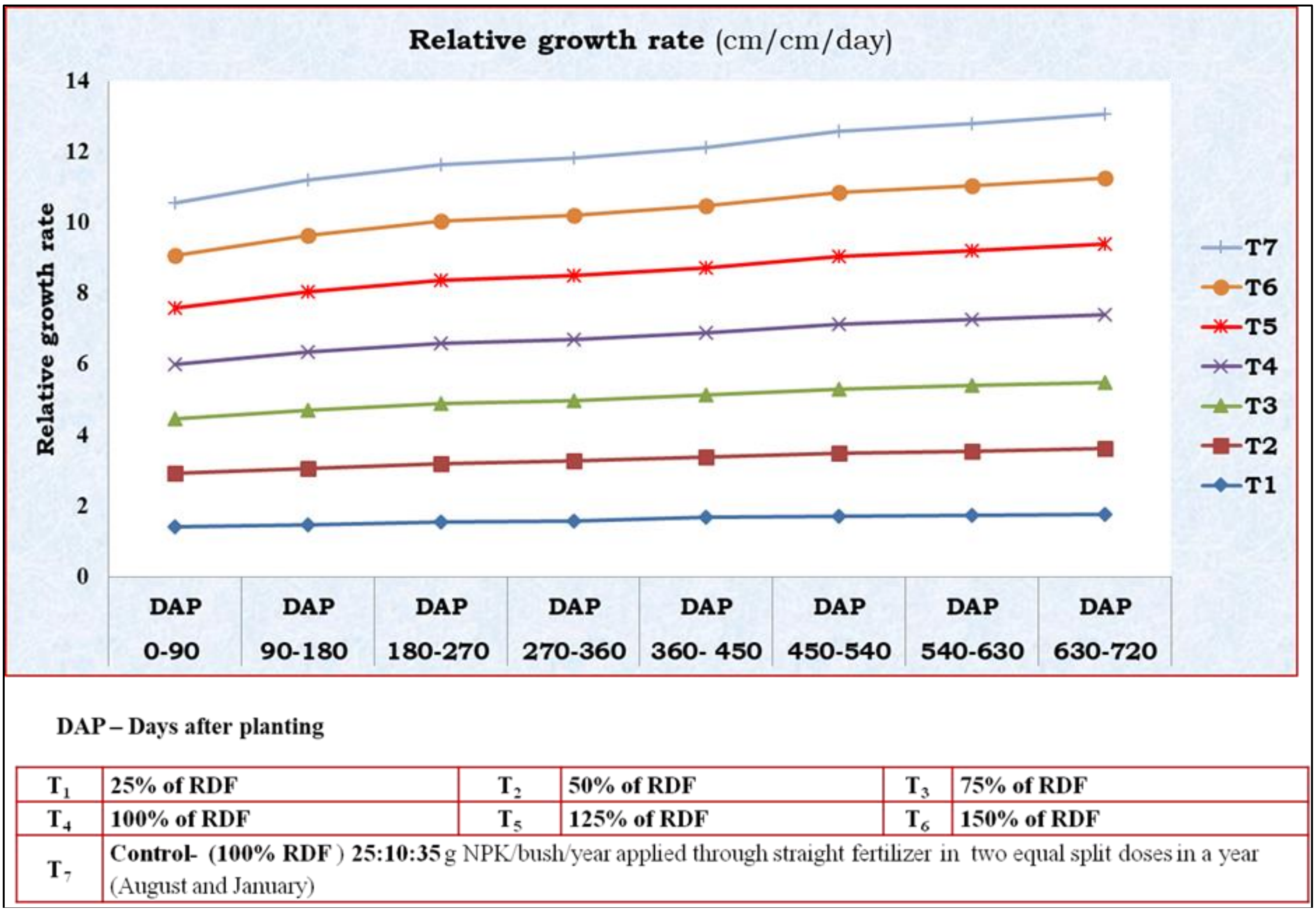

Fig 1: Effect of water soluble fertilizers on Relative growth rate for plant height in bush pepper (cm/cm/day)

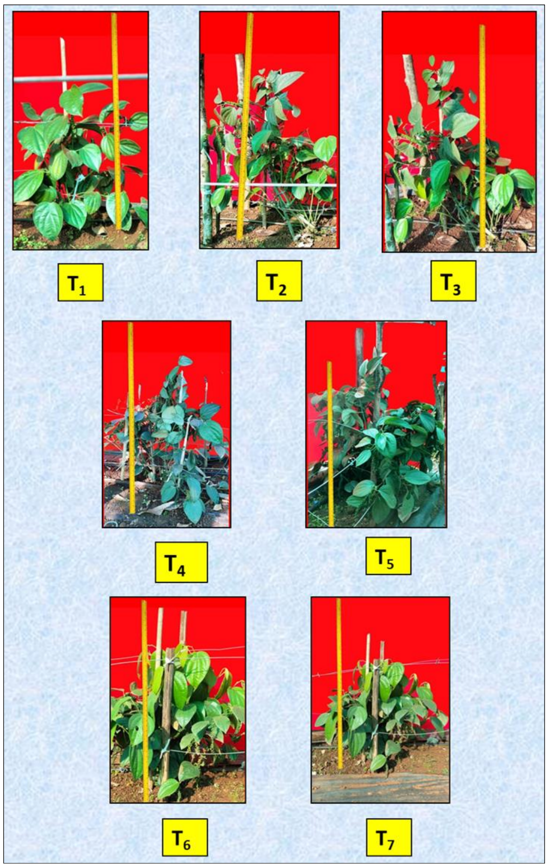

Fig 2: Effect of soluble fertilizers on height of bush pepper

The data obtained in the present investigation was statistically analyzed by the method suggested by Panse and Sukhatme (1995) [28]. The standard error of mean (S.E) was worked out and the critical difference (C.D.) at 5 per cent was calculated wherever the results were found significant.

Results and Discussion

From the table 1 it has been found that growth of bush pepper increased significantly with increasing levels of fertilizers from 25 per cent to 125 per cent but at 150 per cent application of RDF growth of plant declined.

Plant height

Bush pepper is crop of bushy nature and grows up to height of 100 to 150cm. However, application of NPK through water soluble fertilizers promotes the growth over control treatment. In the present experiment the plant height increases significantly with increase in fertilizer level up to T_5 level (125% of recommended fertilizer dose) and increase in fertilizer level (T_6- 150% RDF) results in decrease in plant height. This could be due to the fact that application of fertilizer dose at weekly interval through water soluble fertilizers instantly makes nutrients available needed by the plant for its growth in terms of cell division and cell elongation. The highest dose of fertilizer however reduced the plant height. The plant has certain limitations in potential uptake and utilization of nutrients for its growth and metabolism, beyond which excess application of nutrients will be of no use. The plant height differed significantly at all stages of crop growth. Application of 125 per cent of recommended fertilizer dose (T_5) through WSF recorded the maximum height at 720 days after planting (102.30cm) which was statistically superior over all the other treatments. The minimum plant height at 720 days after planting (58.55 cm) was recorded in treatment T_1 (25% fertilizer dose through WSF). The increase in plant height in the present study might be due to the increased cell division and elongation at higher levels of N. It also might be due to the fact that the nitrogen which is a constituent of chlorophyll increased the synthesis of chlorophyll and have resulted in enhanced photo synthesis and dry matter production which ultimately resulted in better grow thin term of the plant height. Phosphorus is also involved in the energy transfer system in the plant tissues. Hence, it is obvious that a good supply of phosphorus would generally improve the growth. These findings are in close confirmation with the findings of Sat pal *et al*. (2002) [35] and Jilani *et al*. (2008) [14] in brinjal. Premsekhar and Rajashree (2009) [33] reported an increased in plant height in tomato due to foliar application of different grades of water-soluble fertilizers. Similar effects of water soluble fertilizers were reported by Karpakam *et al.* (2004) [15] in brinjal and also by Narayan *et al.* (2012) [24] and Krishnan *et al.* (2014) [17] in tomato and Sakthi *et al*. (2020) [34] in black gram.

New shoots per plant

The number of new shoots was significantly influenced by different levels of fertilizers. The maximum number of new shoots at 720 DAP was recorded by T_5 (125% RDF applied through WSF) i.e., 9.01. However, minimum number of new shoots (5.56) at 720 DAP were observed in treatment T_7 (100% RDF through SF). This increase in mean number of new shoots per plant might be due to the significant influence of NPK on the plant spread and number of new shoots, due to continued vegetative growth resulted by split application of nitrogen. Also the optimum level of NPK had increased the production of more lateral buds, which was reflected in the production of lateral shoots. Increased availability of N, P and K in turn increased physiological process in crop plants and better utilization of nutrients leading to higher number of shoots. These findings are in conformation with Faten *et al*. (2010) [9] in squash gourd, Yassen *et al.* (2011) [46] and Pradeep Kumar (2017) [31] in potato, and Snehitha*et al*. (2019) [41] in marigold.

Primary and secondary branches

The number of primary branches per plant differed significantly among different treatments at 720 DAP. The maximum number of primary branches at 720 DAP was (7.23) produced by the plant supplied with 125 per cent recommended fertilizer dose through soluble fertilizers (T_5) which were at par with T_4, T_6 and T_3 (6.80, 6.33 and 6.45 respectively). The minimum numbers of primary branches were recorded by treatment T_1 (5.08) which was at par with T_7 (5.23). Whereas, The maximum number of secondary branches (3.78) at 720 DAP was produced by the plant supplied with 125 per cent recommended fertilizer dose through soluble fertilizers (T_5) which was at par with T_4 and T_6 (3.45). The minimum numbers of secondary branches was recorded by treatment T_1 (3.00) which was at par with T_2, T_7 and T_3 (3.28, 3.33 and 3.35 respectively). The increased number of primary branches per plant may be due to highest level of N and P at early crop growth stages and uptake of nutrients during different growth stages which might have stimulated more lateral buds to branch out for flowering and fruiting and also increase in higher number of branches might be due to rate of chlorophyll synthesis which caused increase in carbohydrate synthesis responsible for higher vegetative growth. Similar result of better branching with foliar application of nutrients in the form of water soluble fertilizers on tomato was reported by Yadav *et al.* (2001) [45] and Chaurasia *et al.* (2006) [5] in tomato.

Number of leaves per branch

The maximum number of leaves per branch at 720 days after planting was recorded by treatment T_5 i.e., application of 125 per cent of RDF through WSF at weekly interval. (7.43). whereas, minimum number of leaves per branch was found in plants supplied with 100 percent RDF by conventional method (T_7) i.e., 4.15. The number of leaves per plant at all stages of growth differed significantly. Increased in number of leaves might also be due to increased availability of nitrogen, phosphorous and potassium which enhanced production of photosynthetic assimilates from increased photosynthetic rate. The similar results were reported by Mudalagiriyappa *et al.* (2016) [22] and Takankhar *et al.* (2017) [13, 43] in chick pea, Mamathashree *et al.* (2017) [19] in pigon pea, Jadhav *et al.* (2017) [13] in black gram and Nitu *et al.* (2019) [26] in green gram.

Average leaf area

At 720 DAP maximum average leaf area of bush pepper plants was recorded in treatment T_5 *i.e.*, application of 125 per cent of recommended fertilizer dose through water soluble fertilizers (121.62 cm^2) which was statistically superior over rest of the treatments. Whereas, minimum leaf area was recorded by treatment T_1 (25% RDF through WSF) i.e., 72.06 cm^2. The increased leaf area in the best treatment may be due to application of nitrogen which is significant component of nucleic acid such as DNA and chlorophyll which is a constituent of protein which is essential for formation of protoplasm, which promotes the cell division and cell enlargement and ultimately vegetative growth resulted in terms of leaf area. Similar results were also reported by Naik *et al.* (2002) [23] in carrot. Fertigation gives needful flexibility of fertilization which enables the specific nutritional requirements of crops at appropriate stages of growth. The effect of nitrogen in enhancing the leaf area was well established and increased optimum levels usually had positive relationship with growth. Greater leaf area helps the plant to synthesize more metabolites by high photosynthetic rate during the period of growth and development. This result is in agreement with results obtained by Emebiri (2002) [8] and Khandaker *et al.* (2017) [16] in okra.

Plant girth

The plant girth at 720 DAP differed significantly with increasing levels of RDF when fertilizers applied through soluble fertilizers. The maximum plant girth at 720 DAP was observed in treatment T_5 i.e., 125 per cent RDF through WSF. (2.82 cm) which was statistically superior over rest of treatments. However minimum plant girth was recorded by treatment T_1 (25% RDF through WSF) i.e., 1.96 cm at DAP. This increase in plant girth might be due to the higher uptake by roots and accumulation of nutrients in leaf tissues which in turn ensure photosynthetic efficiency causing greater synthesis, translocation and accumulation of carbohydrates. It might also be due to nitrogen which is responsible for the formation, growth and development of the cells and accelerating the synthesis of chlorophyll and amino acid which are associated with major photosynthesis process of plants, it causes an increase in the formation of meristematic tissues. These results are strongly supported by Ghanta *et al.* (1995) [10] in papaya, Mohd. Rafi *et al.* (2002) [21] in tomato, Prakash *et al.* (2002) [32], Acharya & Dashora (2004) [2] and Singh *et al.* (2015) [40] in marigold, Panigrahi *et al.* (2015) [27] in papaya and Anburani (2018) [3] in brinjal. The increasing plant girth also might be due to application of abundance of nitrogenous fertilizer which resulted in increased vegetative growth for photosynthesis activity and secondly nitrogen is a component of nucleic acid such as DNA which is a constituent of protein and is essential for formation of protoplasm, which promotes the cell division and cell enlargement and ultimately vegetative growth. Similar results were also reported by Hazarika and Mohan (1991) [12], Mahalakshmi *et al*. (2001) [18] and Srinivas *et al.* (2001) [42] in banana, Naik *et al.* (2002) [23] in carrot and Neha Sinha *et al.* (2022) [25] in cherry tomato.

Shoot to root ratio

The shoot to root ratio 720 days after planting i.e. at the end of the experiment on the basis ofdry weight was maximum in treatment T_5 (28.87) whereas, minimum shoot to root ratio on the basis of weight was observed in treatment T_1 (21.29). the higher root shoot ratio in treatment T_5 might be due to nutrient supply and demand of root and shoot are inter-dependent due to their different functions, the ratio of root to shoot is an index that reflects growth and dry matter accumulation between root and shoot root growth is closely related to physiological metabolism and dry matter accumulation in shoot. Therefore, it is important to coordinate root and shoot relations and maximize dry matter accumulation and water and nutrient use efficiencies. These findings are in conformation with the findings of Siddique *et al.* (1990) [38], Tomar *et al*. (1997) [44], Marsh and Pierzynski (1998) [20] and Shangguan *et al.* (2004) [37] in wheat.

Relative growth rate (cm/cm/day).

An increasing trend was observed in relative growth rate (RGR) of plant height showed that plant height increased significantly from 0-90 days to 630-720 DAP. The maximum RGR was observed in treatment T_5 (125% of RDF) at 0-90, 90-180, 180-270, 270-360, 360-450, 450-540, 540-630 and 630-720 DAP (1.59, 1.69,1.77, 1.80, 1.83, 1.90, 1.94 and 2.01cm/cm/day, respectively) whereas, minimum relative growth rate was observed in treatment T_1 (25% of RDF) at 0-90, 90-180, 180-270, 270-360, 360-450, 450-540, 540-630 and 630-720 DAP (1.42, 1.48, 1.55, 1.58, 1.68, 1.71, 1.74 and 1.77 cm/cm/day, respectively. An increasing trend was observed in RGR of plant height might be due to the fact that application of fertilizer dose at weekly interval through water soluble fertilizers instantly makes available nutrients needed by the plant for its growth in terms of cell division, cell elongation. These results are in line with findings of Ghule *et al.* (2013) [11] in Bt cotton.

Conclusion

Thus, from the present investigation it is concluded that application of 125 per cent of recommended dose of fertilizer (31.25:12.50:43.75 g NPK/plant/year) through water soluble fertilizer found to be optimum and economically viable as evidenced through maximum growth of bush pepper.

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