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Effect of various mycorrhizal strains on growth and yield attributes of chilli (*Capsicum annuum* L.) cv. Kashi Anmol

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Abstract
An experiment was undertaken to study the effect of mycorrhizae on growth and yield parameters of chilli cv. Kashi Anmol. It was revealed that both the growth and yield parameters performed best with the soil application of Bolt Gr. at an optimum concentration for its application is 10 kg/ha with a single application at 20 DAT. It recorded the minimum days to 50% flowering (40.25 days), highest plant height at 30 DAT (23.70 cm), highest fruit length (6.98 cm), maximum fruit width (1.01 cm), highest fruit weight (3.00 g), maximum number of seeds per fruit (84.00) and maximum test weight (5.59 g). Ratchet with its optimum concentration of 300 mL/ha as foliar application twice at 30 and 60 DAT and Proventus DS with optimum concentration of 100 g/ha as soil application twice at 30 and 60 DAT were recorded as the second best treatment.

Keywords: Optimum, concentration, Bolt Gr., ratchet, Proventus DS

Introduction
Chilli is generally believed to have originated from South and Central America. There are more than 25 species in the genus *Capsicum*, but only five of them are domesticated and grown commercially. These five species are *Capsicum annuum* L., *Capsicum chinense* J., *Capsicum frutescens* L., *Capsicum baccatum* L. and *Capsicum pubescens* K. (Bosland and Votava, 2000; Costa *et al*., 2009) [8, 12]. Since there is difficulty in identifying the intermediary forms that results from the natural interspecific crosses, the former 3 species are now treated as one species (*Capsicum annuum* L.) with four cultivar groups. These cultivar groupings include annuum group (hot chilli), frutescens group (bird chilli), chinense group (West Indies chilli) and sweet pepper group (Nsabiyera *et al*., 2013) [20].

Capsicum annuum is extensively distributed throughout Mexico and South America, but following the Spanish conquest, cultivated forms of the plant reached to South America (Smith and Heiser, 1957) [25]. Bolivia and Peru are major producers of *Capsicum baccatum*. The *Capsicum chinense* is widely grown chilli pepper in the northern parts of South America, West Indies, and the Amazon basin. The widespread distribution and use of chillies throughout tropical, subtropical, and temperate regions of the world serve as proof of their economic significance (Eshbaugh, 1975) [14]. The presence of calyx teeth and a solitary, enormous white blossom at each node distinguish *Capsicum annuum* var. *annuum* from other species. The flower typically grows alone, though it can also appear in pairs. The corolla is bell-shaped, and the calyx is campanulate. In chilli, the anthesis and dehiscence times, pollen viability and germination, as well as stigma receptivity, vary depending upon the location (Kalloo, 1994) [18].

Chilies are well known for being a good source of flavonoids, phenolic acids, carotenoids like beta-carotene and lutein, as well as vitamins A, C, and E, or tocopherols (Palevitch and Craker, 1996) [22]. These substances are widely recognised for having antioxidant qualities (Benzie, 2003) [6]. This antioxidant capacity is shown to be higher than that of several other plants, including onion, mint, ginger, and garlic (Shobana and Naidu, 2000) [24]. In addition to being a great source of vitamins including vitamin B2, vitamin B12, vitamin D3, and vitamin K, fruits additionally provide a greater supply of proteins, carbs, fats, fibre, and mineral salts (El-Ghoraba *et al*., 2013) [13]. These fruit-based substances aid in the prevention of several chronic illnesses including cancer, diabetes, asthma, coughs, and cardiovascular diseases (El-Ghoraba *et al*., 2013; Wahyuni *et al*., 2013) [13, 26].

The microorganisms in the soil play a crucial role in the biogeochemical cycling of nutrients and the availability of these nutrients to the plants in appropriate amounts. Sustainable development of agriculture for maintaining the health of the soil is also an essential aspect and so the role of vesicular arbuscular mycorrhiza (VAM) becomes very important. The symbiotic association between certain fungi and the roots of higher plants results in mycorrhiza. Albert Bernhard Frank first used the word "mycorrhiza" in 1885 (Frank, 1885) [15]. Mycorrhiza literally means "fungus roots" (Bagyaraj, 2014) [4]. The mycorrhizal fungi coexist symbiotically with the roots of most terrestrial plants and are found in soil all over the world. A plant lacking a mycorrhizal root system is unusual in a natural habitat. As a result, it may be claimed that mycorrhizal connection, while widespread, is nearly a ubiquitous phenomenon in the kingdom plantae (Bagyaraj, 2011) [3]. Vesicular arbuscular mycorrhiza are fungi that colonise plant roots and promote plant development and yield, demonstrating their value as beneficial microorganisms. The use of mycorrhiza offers a wise option to be used for increasing the agricultural production and quality along with improved soil health and reduced health hazards. For increasing the agricultural production, mycorrhiza can supplement the chemical fertilizers very efficiently as it increases the availability of nutrients like phosphorus, iron, organic nitrogen, etc. in soil. Keeping in view the above mentioned facts about chilli and mycorrhiza, the present experiment was planned to study the “Effect of various mycorrhizal products on growth and yield attributes of chilli (*Capsicum annuum* L.) cv. Kashi Anmol” under eastern Uttar Pradesh conditions.

Materials and Method

The experiment was conducted under field conditions at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh during Rabi season of 2017-18. The experiment field is situated in the south eastern part of the Varanasi city at 25°264’ North latitude and 83°993’ East longitude at an altitude of 129.23 m above mean sea level. The experiment consisted of 10 treatments each replicated thrice. The treatment were T_1-Control, T_2-Bolt Gr. @ 8 kg/ha soil application × 1 application at 20 DAT, T_3-Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT, T_4-Ratchet @ 300 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_5-Ratchet @ 450 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_6-Ratchet @ 600 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_7-Proventus DS @ 75 g/ha foliar application × 2 applications at 30 and 60 DAT, T_8-Proventus DS @ 100 g/ha foliar application × 2 applications at 30 and 60 DAT, T_9-Proventus DS @ 125 g/ha foliar application × 2 applications at 30 and 60 DAT, T_{10}-Proventus DS @ 100 g/ha soil application × 2 applications at 30 and 60 DAT. Each treatment plot of size 3 × 3 m consisted of 25 plants and all of them were subjected to uniform cultural practices during the course of experimentation. The experiment was performed on chilli plants spaced at 60 × 60 cm^2 spacing laid out in a Complete Randomized Block Design (CRBD) and required parameters were recorded. The variety used in the experiment was Kashi Anmol which was released from ICAR-Indian Institute of Vegetable Research, Varanasi in 2006.

The daily observations were taken to identify the days to 50% flowering. It was calculated by counting the number of days taken by 50% plants (about 13 plants) of a single plot to achieve first flowering. Plant height of 5 tagged plant from each plot was measured with the help of a 60 cm long scale from the base to the terminal growing point of the stem and the average height of the plant was worked out at 30 and 45 days after transplanting (DAT) and at final harvest. Similarly, the total number of branches emerging from the main shoot of 5 tagged plant from each plot were counted at 30 and 45 DAT while measuring the height of the plant and average was worked out. The total number of fruits per plant was calculated by harvesting fruits from the previously tagged plants and counting them after each harvest. Ten fruits were randomly selected per treatment from each replication to determine the length (cm), width (cm) and weight (g) of fruit. Length and width (i.e. diameter) of ten randomly selected fruits was measured with the help of a digital vernier calliper and average was determined. With the help of digital weighing machine, weight of these randomly selected fruits was measured and average weight of the fruit was worked out. Single fruit was randomly selected from each plot and total number of seeds were counted and the average was worked out in the same treatment. A total of 1000 seeds were extracted from fruits from each plot and weighed on a digital weighing machine and average (g) was worked out in the same treatment. Fruit yield per plot was calculated by weighing the total fruits picked from each plot after each picking on a digital weighing balance and all the pickings were summed up. By dividing the fruit yield per plot by total number of plants per plot, fruit yield per plant was calculated. Fruit yield per hectare was worked out the basis of fruit yield per plot. Using the suggested Panse & Sukhatme, 1985 standard approach, the gathered observations were statistically evaluated. Analysis of variance for all treatment in Complete Randomized Block Design (CRBD) was carried out and ANOVA table was used to test the hypothesis.

Result and Discussion

Mycorrhiza significantly improved almost all the characters regarding growth and yield. The plant height represents its growth and vigour. The performance of various mycorrhizal strains on growth and yield parameters has been illustrated in Table 1. The analysis of different parameters revealed that foliar application with Ratchet @ 300 mL/ha × 2 applications at 30 and 60 DAT recorded the maximum plant height at 45 DAT (29.85 cm) and at harvest (74.10 cm). However, soil application with Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT recorded the highest plant height at 30 DAT (23.70 cm). The increased plant height may be due to the increase in the nutrient uptake mechanism as influenced by mycorrhizal inoculation which made the normally unavailable form of nutrients into available form which was easily taken up by the plants. Apart from this aspect, mycorrhiza also made enough water available to the plants for its absorption from the soil through roots. The increased supply of the nutrients mainly resulted in proper cell division as well as cell elongation, leading to increased heights of treated plants. These results are in conformity with the findings of Gurumurthy *et al*. (2014) [16] in chilli, Malik and Vijai (2009) [19] in tomato and Chakraborty *et al*. (2008) [10] in brinjal and tomato. Increased number of branches per plant could be apparently related to the number of flowers and consequently, the number of fruits per plant. Foliar

application with Ratchet @ 300 mL/ha × 2 applications at 30 and 60 DAT recorded the maximum number of branches per plant at 30 and 45 DAT (4.20 and 9.40 branches, respectively). The increased number of branches per plant may be attributed to increased absorption of nutrients such as phosphorus, iron, copper and zinc in the presence of mycorrhizal products. The results are in accordance with the outcomes reported by Bhuvaneswari *et al*. (2014) [7] in chilli, Hadad *et al*. (2012) [17] in tomato and Raveesha *et al*. (2010) [23] in chilli.

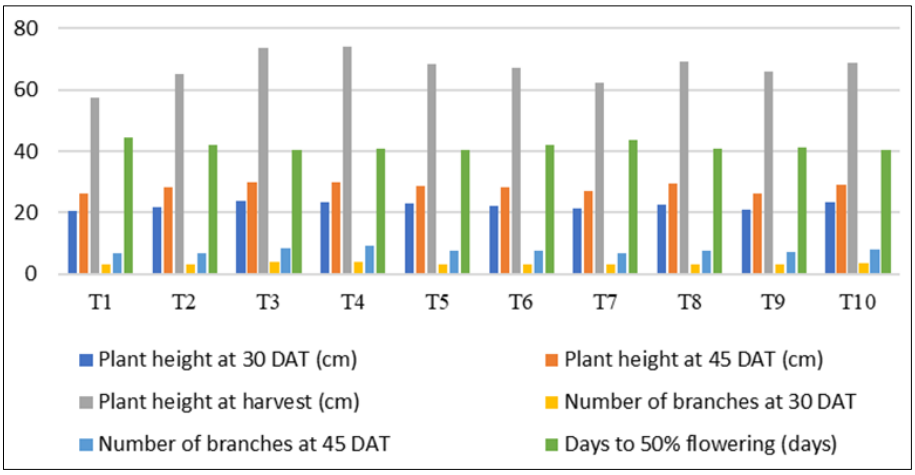

Fig 1: Effect of mycorrhizal on plant height, number of branches and days to 50% flowering

Minimum days to 50% flowering indicated vigorous plant growth, early flowering and consequently early fruiting. The results revealed that soil application with Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT and foliar application with Ratchet @ 450 mL/ha × 2 applications at 30 and 60 DAT exhibited the minimum days to 50% flowering (40.25 days each). The application of mycorrhizal products is responsible for better nutritional status of plant due to appropriate nutrient supply from the soil, particularly phosphorus and zinc absorption and thus, resulting in early flower induction. These results corroborate the findings of Ortas *et al*. (2011) in pepper. Higher number of fruits per plant illustrates vigorous growth of the plant as well as higher flowering. Application of mycorrhizal strains on chilli plants has resulted in substantial upsurge in the number of fruits per plant. Soil application with Proventus DS @ 100 g/ha × 2 applications at 30 and 60 DAT recorded the highest number of fruits per plant (107.45). This may be attributed to increased photosynthetic rate and stomatal conductance with the application of mycorrhiza. The findings corroborate the results of Gurumurthy *et al.* (2014) [16] in chilli, Castillo *et al.* (2013) [9] in chilean pepper plants and Hadad *et al*. (2012) [17] in tomato.

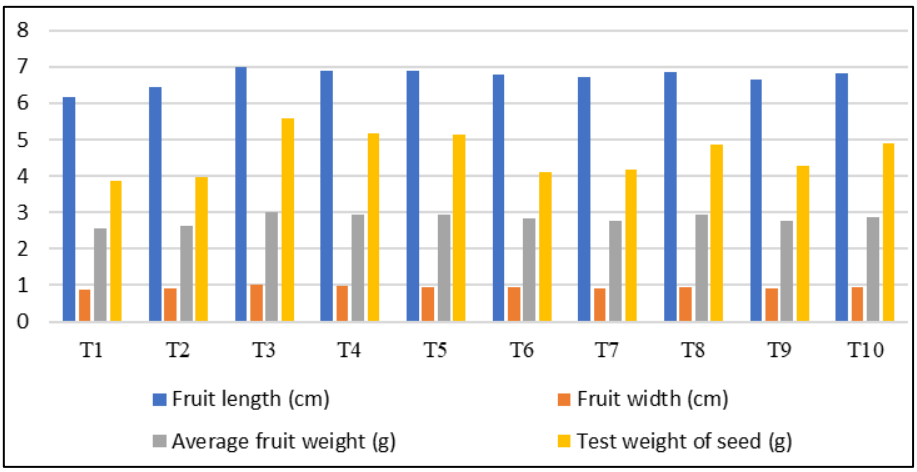

Fig 2: Effect of mycorrhizal on fruit length, width, average fruit weight and test weight of seed

The findings related to the length of the fruit is associated with plant growth and nutrient supply. The highest fruit length (6.98 cm) was observed in soil application with Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT. The inoculation of plants with mycorrhizal products increased the length of the fruit significantly and this might have occurred due to the increased absorption of nutrients. The results were in conformity with the findings of Castillo *et al*. (2013) [9] in Chilean pepper plants. The maximum fruit width (1.01 cm) was recorded in soil application with Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT. The results are in accordance with the findings of Banu *et al*. (2013) [5]. The average weight of the fruit indicates the balanced growth of the plant and adequate nutrient supply to the plant. The highest fruit weight (3.00 g) was reported in soil application with Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT. It was due to increase in the tissue phosphorus, which resulted in the proper formation of nucleic acids and

due to cell division, leading to increased average weight of fruit. These results agree with the findings of Alawathugoda and Dahanayake (2015) [1] in tomato and soybean, Castillo *et al*. (2013) [9] in chilean pepper plant and Hadad *et al*. (2012) [17] in tomato.

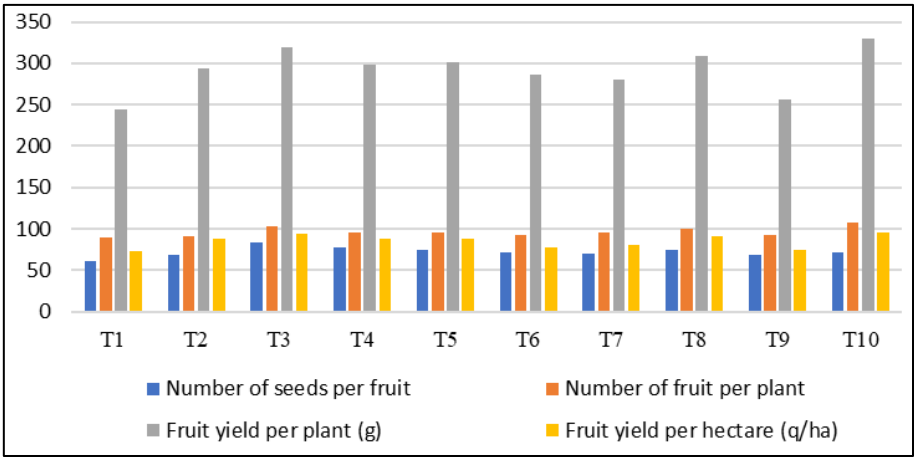

Fig 3: Effect of mycorrhizal on number of seeds per fruit, number of fruit per plant and fruit yield

The maximum fruit yield per plant (329.72 g) was observed in soil application with Proventus DS @ 100 g/ha × 2 applications at 30 and 60 DAT). The increase in fruit yield per plant might be owing to the increased nutrient uptake and proper translocation of phosphorus along with several other nutrients like Mn, Fe, Cu and Zn due to mycorrhizal products application. Higher level of phosphorus in plants inoculated with AM fungi caused increased fruit yield per plant. Similar findings are reported in the work of Gurumurthy *et al*. (2014) [16] in chilli plants, Chakraborty *et al*. (2008) [10] in tomato and brinjal and Constantino *et al*. (2008) [11] in habanero chilli. The highest fruit yield per hectare (95.75 q/ha) was observed in soil application with Proventus DS @ 100 g/ha × 2 applications at 30 and 60 DAT. The significant increase in the fruit yield per hectare was specifically due to better nutrient absorption by plants which resulted in better vegetative growth as well as increased plant biomass. These results are in accordance with the findings of Al-Saidy and Muslih (2009) [2] and Malik and Vijai (2009) [19] in tomato. The maximum number of seeds per fruit (84.00) and maximum test weight (5.59 g) was registered in soil application with Bolt Gr. @ 10 kg/ha × 1 application at 10-20 DAT.

Table 1: Mean performance of various mycorrhizal strains on growth and yield parameters of chilli

Treatment	Plant height at 30 DAT (cm)	Plant height at 45 DAT (cm)	Plant height at harvest (cm)	Number of branches at 30 DAT	Number of branches at 45 DAT	Days to 50% flowering (days)	Number of fruit per plant	Fruit length (cm)	Fruit width (cm)	Average fruit weight (g)	Fruit yield per plant (g)	Fruit yield per hectare (q/ha)	Number of seeds per fruit	Test weight of seed (g)
T_1	20.7	26.36	57.23	3.05	6.85	44.50	89.36	6.16	0.89	2.56	243.80	73.06	61.00	3.87
T_2	21.9	28.33	65.23	3.20	7.00	42.00	91.46	6.45	0.90	2.63	294.03	87.97	69.00	3.98
T_3	23.70	29.75	73.53	3.90	8.60	40.25	102.21	6.98	1.01	3.00	319.01	93.87	84.00	5.59
T_4	23.55	29.85	74.10	4.20	9.40	40.75	95.42	6.89	0.98	2.95	298.05	88.00	78.00	5.18
T_5	22.95	28.85	68.30	3.30	7.55	40.25	95.91	6.88	0.96	2.94	301.53	88.23	75.00	5.15
T_6	22.30	28.45	67.10	3.18	7.45	42.00	92.86	6.79	0.93	2.85	285.80	77.27	71.00	4.10
T_7	21.50	27.00	62.40	3.25	6.90	43.50	95.01	6.73	0.92	2.75	280.50	80.90	70.00	4.18
T_8	22.70	29.35	69.04	3.35	7.75	41.00	99.45	6.84	0.95	2.93	308.89	91.05	74.00	4.86
T_9	21.00	26.42	66.03	3.15	7.28	41.25	93.05	6.63	0.91	2.77	256.10	74.50	68.00	4.28
T_{10}	23.60	29.05	68.80	3.55	8.05	40.50	107.45	6.81	0.94	2.86	329.72	95.75	72.00	4.90
S.E.m. ±	0.62	0.78	2.81	0.21	0.46	0.82	3.16	0.09	0.03	0.20	14.87	4.86	1.91	0.37
C.D. at 5%	1.85	2.33	8.35	0.63	1.37	2.44	9.38	0.26	0.09	0.60	44.17	14.44	5.67	1.09

T_1 - Untreated Control, T_2 - Bolt Gr. @ 8 kg/ha soil application × 1 application at 20 DAT, T_3 - Bolt Gr. @ 10 kg/ha soil application × 1 application at 20 DAT, T_4 - Ratchet @ 300 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_5 - Ratchet @ 450 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_6 - Ratchet @ 600 mL/ha foliar application × 2 applications at 30 and 60 DAT, T_7 - Proventus DS @ 75 g/ha foliar application × 2 applications at 30 and 60 DAT, T_8 - Proventus DS @ 100 g/ha foliar application × 2 applications at 30 and 60 DAT, T_9 - Proventus DS @ 125 g/ha foliar application × 2 applications at 30 and 60 DAT, T_{10} - Proventus DS @ 100 g/ha soil application × 2 applications at 30 and 60 DAT

Conclusion

From the present investigation undertaken, it can be concluded that the superior products for increasing the growth as well as yield parameters was Bolt Gr. and the optimum concentration for its application is 10 kg/ha as soil application with a single application at 20 DAT. However, the second best products were Ratchet with its optimum concentration of 300 mL/ha as foliar application twice at 30 and 60 DAT and Proventus DS with optimum concentration of 100 g/ha as soil application twice at 30 and 60 DAT. In most of the parameters investigated, Ratchet @ 300 mL/ha foliar application twice at 30 and 60 DAT was found to be

statistically at par with soil application of Bolt Gr. @ 10 kg/ha at 20 DAT.

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