Response of broccoli (*Brassica oleraceae* var. italica) to azotobacterbiofertilizer and vermicompost levels

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Abstract-An experiment was carried out on the "Response of broccoli (*Brassica oleraceae var. italica*) to azotobacterbiofertilizer and vermicompost levels" during the growing season of broccoli 2019-2020. Randomized Complete Block Design (RCBD) was used with two factors and replicated thrice. Azotobacterbiofertilizer at the rate of 0, 2, 3 and 4 kg ha^{-1} and vermicompost at the rate of 0, 2, 3 and 4 tons ha^{-1} were used. Azotobacterbiofertilizer significantly increased all the growth and yield attributes of broccoli. Azotobacter application at the rate of 4 kg ha^{-1} significantly increased plant height, plant spread, leaves plant^{-1}, leaf area, curd weight, curd diameter, curd volume, root length, root weight and total yield of broccoli compared with other levels of azotobacter. Maximum plant height (41.9 cm), plant spread (55.3 cm) curd weight (440.6 g), curd volume (327.9 cm^3), root length (22 cm) and root weight (61.4 g) were recorded at 4 kg ha^{-1} of azotobacter while minimum plant height (32.7 cm), plant spread (42.7 cm), curd weight (357.6 g), curd volume (227.9 cm^3), root length (13.1 cm) and root weight (41.4 g) were noted in the control treatment. The application of Vermicompost also significantly improved all the growth and yield attributes of broccoli. Application of vermicompost at the rate of 4 tons ha^{-1} significantly increased plant height, plant spread, leaves plant^{-1}, leaf area, curd weight, curd diameter, curd volume, root length, root weight and yield of broccoli compared with other levels of vermicompost. Maximum plant height (39.8 cm), plant spread (53.1 cm), curd weight (463.9 g), curd volume (384.2 cm^3), root length (20.4 cm) and root weight (57.3 g) were observed at 4 tons ha^{-1} of vermicompost while minimum plant height (33.3 cm), plant spread (42.6 cm),curd weight (322.7 g), curd volume (170.8 cm^3), root length (13.4) and root weight (43.3 g) were recorded in the control treatment. Interaction was found non-significant for most of the parameters except leaves plant^{-1}, leaf area and yield. Maximum leaves plant^{-1} (29),leaf area (474 cm^2) and yield (28.5 tons ha^{-1}) were obtained when azotobacter was applied at the rate of 4 kg ha^{-1} with combination of 4 tons ha^{-1} of vermicompost. Application of 4 kg ha^{-1} of azotobacter and 4 tons ha^{-1} of vermicompost significantly improved the growth and yield of broccoli, however, highest benefit cost ratio for broccoli was recorded with the addition of azotobacter at the rate of 3 kg ha^{-1} along with 2 tons ha^{-1} of vermicompost. The same level of azotobacter and vermicompost is therefore recommended for the highest net return of broccoli.

Key words- Azotobacter, vermicompost, broccoli, growth, yield.

I. INTRODUCTION

Broccoli (*Brassica oleracae. var. italica*) is a member of Brassicaceae family which is also characterized as cole crop. The name of broccoli is originated from an Italian word broccolo which means "the flowering top of a cabbage. About 2000 years ago, broccoli was originated from Italy. It is commonly grown in Italy, China, Thailand, New Zealand, USA, UK, Egypt, India, Israel and Bangladesh (Afrin, 2014).

Broccoli is a shallow rooted crop and dicotyledonous, biennial herbaceous vegetable. It is grown as annual vegetable in winter season for fresh consumption (Ain *et al.*, 2016). It is a nutritive vegetable having protein, minerals, vitamins and anticarcinogenic compounds. It is also rich in sulphoraphane which is play vital role in reducing risk of cancer disease in human beings (Aghajanpour *et al.*, 2017). Hundred grams of fresh broccoli contains protein (3.3%), vitamin-C (137 mg) vitamin-A (3500 IU), vitamin-B_2 (0.12 mg), iron (205 mg g^{-1}) and calcium (0.80 mg)(Chand *et al.*, 2017).

Broccoli is a cross pollinated crop and mostly depends on insects for its pollination. The fruit of broccoli is silique type in which the seeds are produced inside the fruit. Broccoli looks green in color due to the chlorophyll present in the sepal of the floral buds. It grows best in hardy soil and cool weather. However, it can also be grown on light sand to heavy loam or even clay soil that are well supplied organic matter (Singh *et al.*, 2016). It can tolerate pH from 6.8 – 6.0 and have the ability to grow best on pH 7.6 (Ain *et al.*, 2016).

The global production of broccoli (combine with production of cauliflower) is 26.0 million tons. China is the leading producer of broccoli. China and India together accounting for 73% of the world broccoli production followed by United States, Spain, Italy and Mexico each having about one million tons annual production (FAOSTAT (2018). Pakistan ranks eight in broccoli production by producing 220 thousand tons with cultivated area of 13622 hectares (Farooq *et al.* (2018).

Bio-fertilizers are microbial products containing millions of efficient microorganisms which help in improving the availability of bio nutrients to the crop, soil and root (Jha and Sonia, 2008). Bio-fertilizers contain carrier base (liquid/solid) living microorganisms which are helpful for crop in terms of nutrient mobilization, solubilization of phosphorus and nitrogen fixation (Yadav, 2006). Its application improves the activities of beneficial microbes in soil which in turn improves plant growth, yield and quality. Bio-fertilizers are also the cheap and easy sources of nutrients. They are environmental-friendly supplementation in vegetable growing and have the ability to maximize 2 to 45% of yield in vegetable crops (Wani and Lee, 1992). Bio-fertilizers have an important in enhancing the availability of essential nutrients in a workable way. They contain living microorganisms which have the ability of mobilizing nutrients from unavailable form to available form by various biological activities. Azotobacter is free living bacteria which secretes some growth promoting substances and adds nitrogen to non-legume crops under favorable conditions. It plays a vital role by enriching the soil with micro-organisms, nutrients, hormones, insulators, and stabilizers (Mohapatra *et al.*, 2013).

Azotobacter fixes molecular nitrogen from the atmosphere without symbioticrelations with plants. Some Azotobacter species however are associated with plants (Sivasakthi *et al.*, 2017)Azotobacter has useful results not only because of their ability of nitrogen fixation but also have the capacity to produce anti-fungal and anti- bacterial compounds and growth regulation (Mahajan *et al.*, 2003). It has the ability to enhance seed germination rate, shoot and root length. It provides nitrogen and minimizes disease attack and therefore maximizes yield and improve the quality of produce. Its application improves the health of the plants and soil and enhances the crop yields in an effective way (Mrkovacki and Milic, 2001).

Vermicompost is very helpful in improving the physical and nutritional status of the soil and also increases the activity of soil microorganisms. Vermicompost application enhances different types of biological reactions in the soil. It helps in increasing the population of available beneficial microorganism in the soil which work well against different insect pest and disease (Ramesh *et al.*, 2010)

Vermicompost is also known as excellent soil conditioner that can maximize the growth and yield of vegetables crops like Chinese cabbage (Wang Dandan *et al.*, 2006), garlic (Argüello *et al.*, 2006)),peppers (Arancon *et al.*, 2005), tomatoes (Gutiérrez-Miceli *et al.*, 2007) and strawberry (Arancon *et al.*, 2004). Although the output of vermicompost on the growth and yield of vegetables crops is highly flexible. The flexibility may depend on the chemical, physical status of soil, the cultivation practices in which it is applied and biologically status of vermicompost which depends on the species of earthworm which are used, proper feedstock, the vermicompost age and the production process (Roberts *et al.*, 2007, Rodda *et al.*, 2006, Warman and AngLopez, 2010).

Keeping in view the importance of azotobacterbiofertilizer and vermicompost this research was conducted to investigate the effect of azotobacter and to optimize the level of vermicompost for the proper growth and high yields of broccoli.

II. MATERIAL AND METHODS

An experiment entitled "Response of broccoli (*Brassica oleraceae* var. italica) to azotobacter bio fertilizer and vermicompost levels" was conducted during broccoli growing season 2019-2020 at Horticulture Research Farm, The University of Agriculture, Peshawar.

Experimental design

Randomized Complete Block Design (RCBD) was used having two factors and three replications.

Factor A (Azotobacterbiofertilizer levels): 0, 2, 3 and 4 Kg ha^{-1}

Factor B (Vermicompost levels): 0 , 2, 3 and 4tons ha^{-1}

Nursery raising: A nursery bed of 1 meter wide and 15-20 cm of height was prepared. Seeds were sown thinly in lines 10 cm apart and 0.5 cm deep. Seedlings were ready for transplanting when they attained a height of 12-15cm.

Field preparation and layout: The field was well prepared with the help of tractor and the planking pebbles Stones, and previous crops residues were manually removed from the fields. The field was leveled properly. After leveling the field, ridges were made at recommended height. Row to row distance was kept 50 cm. Plants were spaced 40 cm apart.

Application of Azotobacter bio- fertilizer: Slurry was prepared using 200 ml water and 15 g sugar. Then azotobacter was added to the slurry according to the mentioned levels. Then the broccoli Seedling were dipped for 30 minutes in that slurry before transplanting. Healthy and uniform size seedlings were selected and transplanted in well-prepared field. Biozote-max product was used for Azotobacter which contained 10^9 g^{-1} colony farming units (CFU).

Transplantation of seedlings: Four weeks old seedlings were transplanted to the filed in the month of November. Before transplantation filed was irrigated to reduce transplantation shock.

Application of vermicompost: Vermicompost was added with soil to ensure even distribution and it was applied 3 days after transplantation to the base of plants excluding control. Five-centimeter-thick layer of vermicompost was spread around each plant in band according to the levels mentioned in factor B.

Cultural operations: Hoeing, weeding and earthling up were carried out throughout the growing season of the crop. Irrigation was done twice a week.

Observations: The observations were recorded on 5 plants that were randomly selected in each plot in every replication and their mean values were calculated on the following parameters:

Days to curd emergence: The period from transplanting to emergence of first terminal curd for each treatment in each replication was recorded and mean was worked out.

Plant height (cm): From every treatment in each replication five plants of broccoli were randomly selected and their height was measured from the base to the top of the plant at the time of harvest and mean was taken.

Plant spread (cm): Plant spread was measured by measuring east to west and north to south spread of plant using measuring tape at the time of harvest for each treatment in each replication and average values were worked out.

leaves plant $^{-1}$: At maturity, five plants of broccoli were randomly selected in every treatment of each replication and all full-grown leaves of each plant was counted and average number of leaves plant^{-1} was noted.

Leaf area (cm^2): For Leaf area measuring the leaf area meter was used at the time of harvest for five randomly selected leaves from selected broccoli plants and the average was worked out.

Curd weight (g): At the marketable maturity, curds of five randomly selected plants were cut and were weighed singly using electronic balance from each treatment in every replication and their average was taken. Weight was expressed in grams to get single curd weight.

Curd diameter (cm): Diameter of curd was found by dividing the circumference on 3.14 for randomly selected five curds from each treatment in every replication.

Curd volume (cm^3): At marketable maturity stage the terminal curds of five selected plant were cut from each treatment in each replication and the average volume per curd was found using water displacement method.

Root length (cm): Root length (cm) was measured by using measuring tape for five selected plants for each treatment in each replication and their mean was calculated.

Root weight (g): Five plants were selected in each treatment in every replication and their root weight was found with the help of electronic balance at the time of harvest and their average was workout.

Total Yield (tons ha^{-1}): The yield was calculated by adding the weight of all collected fruits at every picking from every replication in each treatment and their mean was worked out based on the area and then converted to tons with the following formula.

$$Total\ Yield\ (tons\ ha^{-1}) = \frac{Yield\ per\ plot\ in\ kg}{Area\ of\ plot} x\ 10000$$

Benefit Cost Ratio (BCR): The benefit cost ratio (BCR) was found by dividing the total benefit on total cost. The income from each plot for each treatment was obtained. The total cost on each treatment was also worked out. Then the total benefit in terms of income was divided by total cost on treatments and their ratio was worked out using the following

$$BenefitCost\ Ratio\ (BCR) = \frac{total\ inome}{total\ cost}$$

Statistical analysis

Data regarding growth and yield attributes of broccoli were recorded during the experiment and analyzed using statistics software Statistics 8.1.Analysis of variance was carried out by using procedure related for RCBD with two factorial arrangements. Means were compared by using LSD test at 0.01 level of probability, when the F-values were observed significant (Steel and Torrie, 1984).

III. Results and Discussion

In the light of previous findings all the results of the study were discussed below.

Days to curd emergence

Days to emergence were affected significantly by the application of azotobacter and vermicompost although their interaction was found not-significant (Table 1).Data concerning different levels of azotobactershowed that broccoli plants took minimum days to emerge curd (88 days) when the plants were applied 4 kg ha^{-1} of azotobacter followed by days to emergence (89 days) at 3 kg ha^{-1} of azotobacter. Maximum days to curd emergence (93 days) were recorded in the control treatment with no application of azotobacter. In case of vermicompost, minimum days to curd emergence (89 days) were recorded at 4 tons ha^{-1} of vermicompost followed by days to emergence (90 days) at 3 tons ha^{-1} of vermicompost.The decrease in days to curd emergence might be due to the fact that azotobacter and vermicompost improved the availability of essential nutrients which are important components of proteins, enzyme, nucleotides and chlorophyll which produced direct and positive effect on vegetative and reproductive growth of the plant (Raghav and Chandra, 2005). The application of vermicompost promote the plant growth and development as it ensure the supply of all essential nutrients which play an important role in the assimilation of carbohydrates (Jaipaul *et al.*, 2011). The same results were recorded by Mal *et al.* (2014) who stated that successive increase in vermicompost levels dramatically reducing the days of curd formation. The same results were also reported by Chaubey *et al.* (2006). They also stated that application of vermicompost at 1.5 tons ha^{-1} increased soil fertility which promoted crop growth and therefore reduced days to curd emergence in cauliflower.

Plant height (cm)

The application of azotobacterbiofertilizer and vermicompost levels significantly improved the plant height while their interaction was found not significant(Table 1).Among different levels of azotobacter, maximum plant height of broccoli (41.9 cm) was recorded when the plants were applied with 4 kg ha^{-1} of azotobacter followed by plant height (37.8 cm) at 3 kg ha^{-1} of azotobacter while lowest plant height (32.7 cm) was noted in control treatment having no application of azotobacter. In case of vermicompost, higher plant height of broccoli (39.8 cm) was recorded for the plots which received vermicompost at 4 tons ha^{-1} followed by plant height (37.9 cm) at 3 tons ha^{-1} of vermicompost. Minimum plant height (33.3 cm) of broccoli was recorded in the control plots.Gajbhiye *et al.* (2003), Rather *et al.* (2003) stated that improvement in plant height might be due to secretions of plant promoting substances by azotobacter. Also, azotobacter efficiently fixed atmospheric nitrogen and converted it to plant available form which in turn promoted plant vegetative growth and resulted in an increased plant height. Sharma (2002) also reported that the secretion by azotobacter enabled plants to uptake more nutrients and thus promoted plant growth. Rasmi*et al.* (2019) stated that the application of azotobacter enhance the height of cauliflower plant as it secrete the growth regulating substances by the microorganism Similarly,Rana and Chandel (2003) stated that plants inoculated with azotobacter attained maximum plant height.Our results are also in line with Sharma (2002) who reported that application of biofertilizer significantly improved the height of broccoli plant. Similar results were also reported by Asm (2019) who stated that biofertilizer significantly increased plant height of cauliflower.Vermicompost had a well-balanced composition of nutrients. Further, it improved the physical condition of soil, promoted the growth of soil micro-flora and helped in the solubilization of mineral elements which ultimately resulted in greater absorption of plant available nutrients throughout the growth period of the plant (Chatterjee *et al.*, 2006). Our result were in agreement with the findings ofCanellas *et al.* (2002) who stated that plant height wasimproved with the application of vermicompost which contained humic acid which helped in thestimulation ofplant's growth. In addition,vermicompost also contained sufficient amount of essential nutrients for plant growth and development.

Plant spread (cm^2)

Plant spread of broccoli was affected significantly by the application of azotobacter and vermicompost while interactive effect of azotobacter and vermicompostregarded plant spread was found non-significant (Table 1).In case of different levels of azotobacter the largest plant spread of broccoli was recorded (55.3 cm^2) when the broccoli plants were applied with 4 kg ha^{-1} of azotobacter followed by plant spread (48.9 cm^2) at 3 kg ha^{-1} of azotobacter while the smallest plant spread (42.7 cm^2) was recorded in control treatment. In terms of vermicompost levels maximum plant spread of broccoli (53.1 cm^2) was recorded at 4 tons ha^{-1} of vermicompost followed by 3 tons ha^{-1} (50.0 cm^2) while minimum plant spread was recorded in control (42.6 cm^2).Improvement in plant spread might be due to essential nutrients which were released by azotobacterbiofertilizer. Those nutrients were found important for the synthesis of protein, enzyme, nucleotides and chlorophyll. These constituents had direct impact on the vegetative growth of the plant (Raghav and Chandra, 2005). Similarly enhancement in plant spread by increasing the level of vermicompost might be due to the supply of all essential nutrients by vermicompost which played an important role in the assimilation of carbohydrates (Jaipaul *et al.*, 2011). (Sharma *et al.*, 2018, Shree *et al.*, 2014) reported that vermicompost application increased crop growth due to the presence of sufficient quantity of nutrients and plant growth hormones. The positive effect of vermicompost application in the present study was similar with the work of Suhane(2007) who concluded that the application of vermicompost increased the soil organic content and also improved the physical condition of soil along with its chemical properties. In addition, vermicompostcomprised enzymes like chitinase, cellulase, amylase and lipase which played role in the breakdown of soil organic matter and provided essential nutrients to the plant which promoted the growth of plant (Chaoui *et al.*, 2003). The combination of vermicompost with biofertilizers increased the production by 15.9% over the control (Jeyabal and Kuppuswamy, 2001). Similar results were reported by Asm (2019) who stated that biofertilizer significantly increased plant spread in cauliflower.

Leaves plant $^{-1}$

Significant effect was observed by the azotobacter bio fertilizer and vermicompost application on leaves $plant^{-1}$ of broccoli. Their interaction was also found significant for leaves $plant^{-1}$(Table 1).Among different levels of azotobacterbiofertilizer, maximum leaves $plant^{-1}$ (26) was recorded at 4 kg ha^{-1} of azotobacter while lowest leaves $plant^{-1}$ (16) was noted on control. In case of vermicompost, highest leaves $plant^{-1}$ (24) was noted with the vermicompost application at the rate of 4 tons ha^{-1} followed by leaves (23) at 3 tons ha^{-1} while the lowest number of leaves (18) was noted on control. Data regarding interaction revealed that highest leaves $plant^{-1}$(29) were recorded at 4 kg ha^{-1} of azotobacter with combination of 4 tons ha^{-1} of vermicompost. Azotobacter and vermicompost both promoted vegetative growth of the plant and enhanced the production of leaves. Increase in the number of leaves might be the result of microbial inoculation which released certain substances that promoted the growth and increased the availability of nitrogen (Kumar *et al.*, 2015). (Bhardwaj *et al.*, 2007, Rather *et al.*, 2003) reported that plants which were applied with biofertilizers produced higher number of leaves $plant^{-1}$ compared to control. Yadav *et al.* (2012) also reported increase in the number of leaves with application of bio fertilizer (azotobacter).This might be due to increased nutrient availability particularly nitrogen through nitrogen fixation which in turn increased vegetative growth (Meena *et al.*, 2017). Bhardwaj *et al.* (2007) reported that azotobacterbiofertilizers released secondary metabolites which speedup nutrient uptake by plant. These findings are supported by many other researchers who reported improvement in broccoli growth and productivity with the application of azotobacter and vermicompost (Yadav *et al.* (2012) and(Burr *et al.*, 1978, Sharma *et al.*, 2018). Sharma and Banik (2014) also reported that vermicompost contain large amounts of C and N compounds. Moreover, vermicompost provided essential nutrients to plant, improved soil properties and enhanced root biomass which ultimately increased leaves number. Our results are in line with Walker and Bernal (2005) and (Reza *et al.*, 2016).

Leaf area (cm^2)

Data pertaining to leaf area revealed that azotobacter, vermicompost and their interaction significantly affected leaf area of broccoli (Table 1).Data regarding different levels of azotobacter showed that greater leaf area (322 cm^2) was recorded at 4 kg ha^{-1} of azotobacter while smaller leaf area (162 cm^2) was noted in control plots. In case of vermicompost application, the highest leaf area (344 cm^2) was recorded for 4 tons ha^{-1} followed by leaf area (260 cm^2) at 3 tons ha^{-1} while lowest leaf area (167 cm^2) was recorded in control plots. The maximum leaf area (474 cm^2) was noted when azotobacter was applied at 4 kg ha^{-1} along with 4 tons ha^{-1} of vermicompost.Azotobacter and vermicompost both have the ability to ensure the proper supply of plant essential nutrients particularly nitrogen to the plant. They also improve the soil physical properties and therefore provide suitable environment for plant growth. Vermicompost supplies the growth promoting substances such as humic acids and important growth regulators like auxins, gibberellins and cytokinin's which are the key sources for increasing the plant growth and yield of broccoli. Biofertilizer like azotobacter is used to enhance the fertility and structure of the soil. It offers an economically attractive and ecologically safe route of nutrient supply that enables plant to growth and produce well (Anil *et al*., 2015). Vimala and Natarajan (2002) also stated that azotobacter use greatly contributed to the vigorous growth of plant. Singh *et al.* (2009) reported significant improvement in growth parameters like leaf area in broccoli with the use of azotobacter. Vermicompost application also ensured longer and sustained supply of nutrients during the entire growth period of plant and therefore enhanced the leaf area of various vegetables including broccoli (Raghav and Chandra, 2005); (Sharma *et al.*, 2018, Shree *et al.*, 2014)

Curd weight (g)

Data regarding curd weight showed significant variation among azotobacterbiofertilizer and vermicompost. However, their interaction was found non-significant (Table 2). In case of different levels of azotobacter the highest curd weight (440.6 g) was noted for 4 kg ha^{-1} of azotobacter followed by curd weight (419.2 g) for 3 kg ha^{-1} while the minimum curd weight of 357 g was recorded in the control plots. In case of vermicompost levels, highest curd weight (463 g) was recorded for 4 tons ha^{-1} followed by curd weight (447.0 g) for 3 tons ha^{-1} of vermicompost while the minimum curd weight (322.7 g) was observed in the control plots.Improvement in curd weight with increasing levels of azotobacterbiofertilizer might be due to better fixation of nitrogen by azotobacter which accelerated the synthesis of chlorophyll, amino acids, enzyme and carbohydrates (Bashyal, 2011).Asm (2019) reported that biofertilizer use significantly increased curd weight of cauliflower. Similar observations were also reported by (Raghav and Chandra, 2005). Vermicompost also increased curd weight of broccoli which might be due to the supply of all essential nutrients that helps in the synthesis of carbohydrates (Jaipaul *et al.*, 2011); (Sharma *et al.*, 2018, Shree *et al.*, 2014). Moreover, application of vermicompost improves the soil structure and increases microbial activity. Therefore vermicompost use increased cabbage head weight and overall production as compared to the alone application of synthetic fertilizers (Reza *et al.*, 2016). The results are also in same with the results of Canellas *et al.* (2002). They concluded that increased in curd weight by the application of vermicompost. In addition, vermicompost retained required amount of macro and micronutrients, including vital NPK and micro nutrients longer than conventional compost (Sánchez *et al.*, 2017). (Suhane, 2007) reported that vermicompost provides essential nutrients to plant roots and promotes growth, increases the soil organic content and therefore improves efficiency of soil microorganism (Singh, 1993). In addition, vermicompost contains different types of enzymes such as amylase, cellulase, lipase, and chitinase, which help in the breakdown of soil organic matter and releases various nutrients slowly to the root zone. Such improvements provide favorable environment for the growth of plant and helps

Curd diameter (cm)

Data regarding curd diameter of broccoli was significantly affected by the application of azotobacter and vermicompost while the interactive effect of azotobacter and vermicompost was recorded non-significant (Table 2).In case of azotobacter, maximum curd diameter (18.0 cm) was reported when the plants were applied with 4 kg ha^{-1} of azotobacter followed by 3 kg ha^{-1} (16.5 cm) while minimum curd diameter (13.5 cm) was recorded in control plots. Data pertaining to vermicompost levels showed that the maximum curd diameter (21.1 cm) was recorded at 4 tons ha^{-1} followed by 3 tons ha^{-1} (15.8 cm) of vermicompost while minimum curd diameter (12.5 cm) was recorded in control plots.Azotobacter secretes growth promoting substances. It also fixes atmospheric nitrogen which helps in the development of vegetative parts of the plant. This in turn improves yield of the crop by producing quality curds with maximum diameter (Bhardwaj *et al.*, 2007). Increase in curd diameter may also be due to continuous supply of all essential nutrients from vermicompost, which might have helped in the carbohydrates assimilation in plant (Jaipaul *et al.*, 2011). Arisha *et al.* (2003) revealed that vermicompost stimulates the growth of beneficial microorganisms which releases phyto-hormones and promotes the absorption of nutrients and plant growth. Similar results have also been reported byEkta *et al.*(2017)in increasing the productivity.

Curd volume (cm^3)

Data regarding curd volume revealed that curd volume was significantly affected by azotobacter and vermicompost while interactive effect of azotobacter and vermicompost was observed not significant (Table 2).Application of azotobacter significantly increase curd volume, the highest curd volume (327.9 cm^3) was recorded with azotobacter at the rate of 4 kg ha^{-1} followed by 3 kg ha^{-1} (312.1 cm^3) while the lowest curd volume (227.5 cm^3) was noted in control plots. Additionally, application of vermicompost at the rate of 4 tons ha $^{-1}$ produced highest crud volume (384.2 cm^3) followed by 3 tons ha^{-1} (313.8 cm^3) while lowest curd volume (170.8 cm^3) was recorded in control. Increase in curd volume might be due to release of sufficient quantity of nutrients by azotobacter and vermicompost that in turn produced high dry matter content in plant (Sharma *et al.*, 2018, Shree *et al.*, 2014). Raghav and Chandra (2005) also reported that increase in curd volume might be due to the fact that azotobacter fixed sufficient quantity of atmospheric nitrogen in plant available form which was absorbed by plant roots. Nitrogen along with other nutrients therefore promoted curd growth. The resuts of the present study are also supported by the findings of (Jeyabal and Kuppuswamy, 2001). The vermicompost had greater role in the proper growth of plant as it improve the physical condition of soil and also its chemical and biological properties. Application of azotobacter and vermicompost facilitated the absorption of nutrientsby roots which improved bothvegetative and reproductive growth(Chaterjee *et al.*, 2005).

Root length (cm)

Data regarding root length of broccoli was significantly affected by the application of azotobacter and vermicompost and their interaction (Table 3).In case of azotobacter application maximum root length (22 cm) was noted at 4 kg ha^{-1} of azotobacter followed by 3 kg ha^{-1} (18.1 cm) while lesser root length (13.1 cm) was recorded in control plots. In case of vermicompost application, higher root length (20.4 cm) was recorded at 4 tons ha^{-1} followed by 3 tons ha^{-1} (19 cm) while lesser root length (13.4 cm) was recorded in control plots.Increase in root length in broccoli with vermicompost application might be due to the reason the vermicompost make the soil structure more favorable for root growth due to the decreasing soil bulk density and increase availability of sufficient amount of mineral nutrients to crop roots (Shashidhara, 2000). Our results are similar with Altuntas (2018) who reported that azotobacter application improved the nitrogen availability in root zone of the plant which significantly increased root length of the plant. It was also concluded that the application of azotobacter reduced the use of chemical fertilizers and eliminated the problems related with plant growth (Shaharoona *et al.*, 2008); (Dauda *et al.*, 2008). Our results are also in agreement with Karlen and Camp (1985) who concluded that application of vermicompost improved root length of crop by enhancing properties of soil like fertility, porosity, and water holding capacity of soil that resulted in better root growth.

Root weight (g)

A significant variation was observed in root weight by the application of azotobacter and vermicompost although their interaction was found not significant (Table 3).Data regarding different levels of azotobacter revealed that higher root weight of broccoli was gained by the plants applied at 4 kg ha^{-1} of azotobacter that was (61.4 g) while lesser root weight (41.4 g) was recorded in the control plots. among the levels of vermicompost application, higher root weight (57.3 g) was recorded at 4 tons ha^{-1} of vermicompost while lesser root weight (43.3 g) was recorded in control.our results are in line with (Atal *et al.*, 2019) who reported that combine application of vermicompost and azotobacter significantly increased root dry weight of broccoli. Similar results was also observed by (Ali and Kashem, 2018) who revealed that vermicompost application as organic manure with the application of azotobacter improved soil structure and nutrient status of the soil which therefore provided favorable conditions for root growth. Bhardwaj *et al.* (2007) concluded that application of biofertilizer secreted growth promoting substances which developed the root system of plant. The results are also in agreement with the report of (Ekta *et al.*, 2017). Similar results were also reported by (Salim *et al.*, 2018) who stated that azotobacterbiofertilizer improved the growth of broccoli .

Yield (tons ha^{-1})

The data regarding yield (tons ha^{-1})of broccoli are present in table 11 and the analysis of variance is shown in table 11a. The yield of broccoli was significantly affected by the application of azotobacter, vermicompost and their interaction (Table 3).Among different levels of azotobacter the maximum yield (22.7 tons) was recorded at 4 kg ha^{-1} followed by yield (21.3 tons) at 3 kg ha^{-1} while minimum yield (16.8 tons) was recorded in the control plots. In case of vermicompost the highest yield (24.6 tons)was produced by broccoli at 4 tons ha^{-1} followed by 3 tons ha^{-1} (22.2 tons) while lowest yield of broccoli (13.4 tons) was recorded in the control plots.Increase in the yield of broccoli with higher levels of azotobacter as well as vermicompost might be due to the fact that both amendments improved soil structure, soil biodiversity and nutrient status of growing medium. All such improvements enhanced the vegetative growth of broccoli. Healthy plants had efficient metabolic processes which helped in the production of healthy curds and therefore resulted in the improvement of total yield. Similar results were also recorded by Wange and Kale (2004). They reported that azotobacter significantly the yield of broccoli as compared to conventional fertilizers alone. Manivannan and Singh (2004) reported that azotobacter enhanced the growth and yield of sprouting broccoli when applied at 5 percent. Singh and Singh (2004) reported that application of vermicompost in cauliflower significantly increase yield. Similarly, Sharma *et al.* (2008) reported increase in yield of sprouting broccoli with application of vermicompost. Our results are in line with Padamwar and Dakore (2009) who conducted field trial on cauliflower and applied organic manures (farmyard manure, vermicompost and bio fertilizers) to observe their effect on growth, yield and nutritional value. The vermicompost application was found better for cauliflower growing with respect to yield and quality cauliflower. in increasing the yield and quality of cauliflower. Application of vermicompost enhanced biophysical properties of the soil, which enhanced soil fertility and productivity as a result increase crop yield. Swarup (2008) reported that increase soil organic matter through application of vermicompost increased macro and micronutrient availability in the soil and make it more readily available to the plant to absorbed, which ultimately increase crop yield. Marashi and Scullion (2003) and Frouz*et al.* (2008) also reported that soil application of vermicompost can improved properties of soil such as soil aggregate formation, the activity of microflora and the soil water holding capacity Jaipaul *et al.* (2011), Sharma *et al.* (2018) and Shree *et al.* (2014) reported that improvement in yield was observed in vegetable crops due to continuous supply of nutrients that are essential for plant growth and development.

Benefits Cost ratio (BCR) ha^{-1}

Data regarding benefit cost ratio is given in Table 4. The costs of different levels of azotobacter and vermicompost were noted when calculating the benefit cost ratio. Expenses for all cultural practices were included for each treatment of azotobacter and vermicompost. The total cost and income were also calculated for control plot. The highest benefit cost ratio (10.3) was recorded at 3 kg ha^{-1} of azotobacter with 2 tones ha^{-1} of vermicompost, followed by BCR (10.0) at 4 kg ha^{-1} of azotobacter with 2 tones ha^{-1} of vermicompost. While the lowest benefit cost ratio (7.0) was noted in control withoutany application of azotobacter and vermicompost.

IV. CONCLUSIONS

From the results it was concluded that application of azotobacter at the rate of 4 kg ha^{-1} significantly increased plant height, plant spread, no of leaves, curd weight, curd volume, root weight, root length, and yield of broccoli. Application of vermicompost at the rate of 4 tons ha^{-1} significantly increased the growth and yield of broccoli.Addition of azotobacter at 3 kg ha^{-1} along vermicompost at 2 tons ha^{-1} resulted in highest benefit cost ratio for broccoli as compared to other levels.

V. RECOMMENDATION

Application of 4 kg ha^{-1} of azotobacter and 4 tons ha^{-1} of vermicompost significantly improved the growth and yield of broccoli, however, the highest benefit cost ratio for broccoli was recorded with the addition of azotobacter at the rate of 3 kg ha^{-1} along with 2 tons ha^{-1} of vermicompost. The same level of azotobacter and vermicompost is therefore recommended for the highest net return of broccoli.

Table 1. Plant height (cm), plant spread (cm^2), number of leaves $plant^{-1}$ and leaf area (cm^2) of Broccoli as influenced by different levels of azotobacter and vermicompos. t

Azotobacterbiofertilizer	Plant height (cm)	Plant spread (cm^2)	Leaves $plant^{-1}$	leaf area (cm^2)
Control	32.7 D	42.7 D	16 D	162 D
2 kg ha^{-1}	35.0 C	44.9 C	21 C	223 C
3 kg ha^{-1}	37.8 B	48.9 B	23 B	262 B

4 kg ha^{-1}	41.9 A	53.3 A	26 A	322 A
Vermicompost				
Control	33.3 D	42.6 D	18 C	167 D
2 kg ha^{-1}	36.4 C	46.3 C	21 B	198 C
3 kg ha^{-1}	37.9 B	50.0 B	23 A	260 B
4 kg ha^{-1}	39.8 A	53.1 A	24 A	344 A
LSD (P ≤ 0.01)	1.4	2.0	1.4	19.1
Interaction				
Azotobacter× Vermicompost	NS	NS	2.77	38.23

Table 2. Curd weight (g), curd diameter (cm) and curd volume (cm^{-3}) of broccoli as influenced by different levels of azotobacter and vermicompost.

Azotobacterbiofertilizer	Curd weight (g)	curd diameter (cm)	Curd volume (cm^{3})
Control	357.6 C	13.5 D	227.5 b
2 kg ha^{-1}	402.7 B	15.5 C	272.1 ab
3 kg ha^{-1}	419.2 B	16.5 B	312.1 b
4 kg ha^{-1}	440.6 A	18.0 A	327.9 a
Vermicompost			
Control	322.7 C	12.5 D	170.8 B
2 kg ha^{-1}	386.4 B	14.1 C	270.8 A
3 kg ha^{-1}	447.0 A	15.8 B	313.8 A
4 kg ha^{-1}	463.9 A	21.1A	384.2 A
LSD (P ≤ 0.01)	1.4	2.0	19.1
Interaction			
Azotobacter× **Vermicompost**	**NS**	**NS**	**NS**

NS: Non-Significant

Table 3. Root length (cm), Root weight (cm) and yield (tons ha^{-1})of broccoli as influenced by different levels of azotobacterand vermicompost.

Azotobacterbiofertilizer	Root length (cm)	Root weight (cm)	Yield (tons ha^{-1})
Control	13.1 D	41.4 C	16.8 D
2 kg ha^{-1}	15.3 C	46.2 C	18.4 C
3 kg ha^{-1}	18.1 B	53.9 B	21.3 B
4 kg ha^{-1}	22.0 A	61.4 A	22.7 A
Vermicompost			
Control	13.4 C	43.3 b	13.4 D
2 kg ha^{-1}	15.6 B	48.8 b	19.1 C
3 kg ha^{-1}	19.0 A	53.4 ab	22.2 B
4 kg ha^{-1}	20.4 A	57.3 a	24.6 A
LSD (p ≤ 0.05, p ≤ 0.01)	1.9	7.3	1.3
Interaction			
Azotobacter×Vermicompost	NS	NS	2.7

Table 4. Benefit Cost Ratio (BCR) ha^{-1} of broccoli as influenced by different levels of azotobacter and vermicompost.

Azotobacter (kg ha^{-1})	Vermi-compost (tons ha^{-1})	Benefit ha^{-1} (Rs)	Cost ha^{-1} (Rs)	B:C ratio
0	0	275400	39113	7.0
0	2	629333	74646	8.4
0	3	800000	93913	8.5
0	4	853333	110246	7.7
2	2	733333	78846	9.3
2	3	872667	97329	9.0
2	4	854667	111879	7.6
3	2	853333	82646	10.3
3	3	886667	98479	9.0
3	4	1120000	119313	9.4
4	2	833333	82946	10.0
4	3	986667	101779	9.7
4	4	1100000	119613	9.2

INPUTS APPLIED	RATE (RS)	INPUTS APPLIED	RATE (RS)
UREA	36 kg^{-1}	Vermicompost	15 kg^{-1}
DAP	44 kg^{-1}	Azotobacter	800 kg^{-1}
LABOR	1000 day	Seed	1000 g^{-1}
IRRIGATION CANNEL	200 season^{-1}	Transport	1000 tn^{-1}

ROTAVATOR	1500 hr^{-1}	Harvesting	2000 hr^{-1}
Kg: kilogram,	hr: hour	tn: turn	

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