Elucidating the Role of Bioinoculants on Growth Attributes of Chillies (*Capsicum Annuum* L.)

S. Jidhu Vaishnavi [1*], P. Jeyakumar [2], C.N. Chandrasekhar [3]

[1, 2, 3] Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

[1]Amrita School of Agricultural Sciences, Amrita Viswa vidhyapeetham, Coimbatore, Tamil Nadu, India.

Email: [1] sjvaishnavi@gmail.com

Abstract

Bioinoculants are the environmental friendly microorganisms involved in growth and development of Chillies. Growth is measured in terms of increase in biomass and leaf area contributing for maximum dry matter accumulation and crop yield of chillies. The leaf improvement directly increases the leaf area index, leaf area duration, specific leaf weight and biomass in terms of crop growth rate of chillies. *NovoBac* seed treatment @ 2g/kg + soil drenching @ 500g/ha improved the growth attributes of chillies which are physiologically important predictors for improving the yield of chillies. Bioinoculants helps in improving the nutrient uptake of the chillies, thus involving the improvement in leaf area and volume of biomass of chillies.

Keywords: Bioinoculant, *NovoBac*, *Bacillus*, Chillies, Growth.

1. Introduction

Chillies, a fascinating crop is grown for vegetables, spices, condiment, sauces and pickles. It is known for the pleasant aromatic flavour, pungency and high colouring substance. Both green and dry chillies are produced all over the world. Chillies is an annual shrub, highly branched; leaves are simple, alternate, exstipulate, elliptic, lanceolate and glabrous with unequal margin. Chillies is grown in an area of approximately 1.83 million hectares with an average global productivity of 1.62 tonnes per hectare (www.thehindubusinessline. com). India is the world leader in chillies production (43%) followed by China and Pakistan. India produced 1.35MT of dry chillies from an area of 0.80 million hectares during 2008-09. Increasing use of chemical inputs causes several negative effects, i.e., development of pathogen resistance to the applied agents and their non-target environmental impacts (Gerhardson 2002). A growing awareness that agricultural practices have a great impact on human health and on the environment has spawned research into the development of effective bio-control agents to protect crop plants against diseases. Bioinoculants contain neither fertilizer nor pesticide, but possess biologically active substance which when applied to a plant will enhance the growth of the plant and are often used as supplements in present agricultural practices in crop production. A bioinoculant may increase metabolism, increase chlorophyll efficiency and production, increase antioxidant production, enhance nutrient availability, speed up germination and cell development or increase the water holding capacity of plant cells or even the soil. *NovoBac* is a new bioinoculant promoted by Novozymes South Asia, Bangalore. It is a natural, soluble, beneficial microbial formulation. It is mainly used in greenhouse/ nursery, field and vegetable crops, root crops, turf and athletic fields. It can be applied as seed treatment, soil drenching, and drip or direct to soil media and also as fertilizer. *NovoBac* improves root development thus, improve nutrient uptake and growth of chillies. The composition of *NovoBac* includes the *Bacillus* sp. inoculant amounting to a minimum of 8.5 x 10^9 cfu/g. With this background, the present investigation was carried out to find out the effect of bioinoculant (*NovoBac*) as seed treatment, drenching and their combination on growth attributes of chillies.

2. Materials and Methods

The experiment was conducted in Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during the period of November 2010 to May 2011. In this experiment, the bioinoculant (*NovoBac*) was given as seed treatment and as soil drenching or in combination to chillies (TNAU chilli hybrid Co1) and observations were recorded from 30 days after transplanting (DAT) till 150 DAT. The experiment had 3 replications and 10 treatments including T_1-Control, T_2-*Trichoderma viride* seed treatment @ 4 g/kg , T_3-*NovoBac* Seed treatment @ 1 g/kg, T_4-*NovoBac* Seed treatment @ 2 g/kg, T_5-*NovoBac* Soil drenching @ 250 g/ha on 15 DAT, T_6-*NovoBac* Soil drenching @ 500 g/ha on 15 DAT, T_7-*NovoBac* Seed treatment @ 1 g/kg + Soil drenching @ 250 g/ha on 15 DAT, T_8-*NovoBac* Seed treatment @ 2 g/kg + Soil drenching @ 250 g/ha on 15 DAT, T_9-*NovoBac* Seed treatment @ 1 g/kg + Soil drenching @ 500 g/ha on 15 DAT and T_{10}-*NovoBac* Seed treatment @ 2 g/kg + Soil drenching @ 500 g/ha on 15 DAT. Observations including leaf area index (Williams 1946), leaf area duration (Power *et al.*, 1967), specific leaf weight (Pearce *et al*., 1968), crop growth rate (Watson 1956) and total dry matter accumulation were observed at 30DAT, 60 DAT, 90 DAT, 120 DAT and 150 DAT. Seedlings survived after transplanting were counted and compared with number of plants transplanted and expressed in percentage. The data collected were subjected to statistical analysis in randomized block design following the method of Gomez and Gomez (1984).

3. Results and Discussion

Leaf Area Index (LAI): LAI indicates the quantum of leaf area produced per unit land area and it is considered as an important factor to determine the dry matter production and net photosynthetic rate. Therefore, early attainment of an optimum LAI is considered as a pre-requisite for higher biomass production. The time trend increases the LAI significantly, irrespective of the treatments. The increase in LAI in T_{10} (*NovoBac* seed treatment 2g/kg + soil drenching @ 500 g ha^{-1} on 15 DAT) was 23 per cent when compared with the control (Table 1). Maintenance of high LAI at fruiting stage always have a direct impact on better partitioning of the assimilates to yield (Tsai, 1984). The increase in LAI was due to the effect of *Bacillus* present in *NovoBac* enhance the nutrient uptake and improve the leaf area of chillies. Hansen (1972) reported that peak LAI is an important factor for increased photosynthesis. The higher values of growth attributes, would lead to greater metabolic substances and therefore more photosynthetic activity. Similar results have been reported by Amal *et al.* (2010) in sorghum. Pandey and Singh (1981) stated that senescence and abscission of the older leaves might cause the depletion of LAI at the later stages of growth.

The reduction in LAI in control plants is directly correlated with the leaf area of the control plot.

Table 1: Effect of bioinoculant (*NovoBac*) on Leaf Area Index at different growth stages of chillies

Treatment	30DAT	60DAT	90DAT	120DAT	150DAT
T_1	0.897	1.733	1.882	2.031	2.055
T_2	1.031	1.923	2.145	2.415	2.666
T_3	0.997	1.854	2.063	2.251	2.343
T_4	1.011	1.880	2.134	2.368	2.642
T_5	0.956	1.739	1.927	2.115	2.152
T_6	0.961	1.758	2.004	2.250	2.302
T_7	1.033	1.876	2.151	2.421	2.679
T_8	1.048	1.936	2.266	2.595	2.874
T_9	1.043	1.923	2.211	2.498	2.680
T_{10}	1.096	2.012	2.331	2.650	2.878
Mean	**1.008**	**1.864**	**2.126**	**2.360**	**2.528**
SEd	**0.003**	**0.005**	**0.007**	**0.010**	**0.014**
CD (P:0.05)	**0.006**	**0.009**	**0.015**	**0.020**	**0.030**

Leaf Area Duration (LAD): LAD is a measure of the duration of photosynthetic apparatus up to which it can accumulate the dry matter for growth and development (Wetblank *et al.*, 1966). In the present study, LAD varied significantly among the treatments. Treatment T_{10} shows maximum LAD compared to other treatments and an increase of 23.93 per cent compared to control was observed (Table 2). Formation of optimum photosynthetic area and maintenance of photosynthetically actives leaves for a longer duration especially during the reproductive phase of the crop is essential for increasing the photosynthetic rate, dry matter accumulation and grain yield (Watson, 1956). In capsicum, an increase in LAD was obtained with nitrogen fertilizers (Javier *et al.*, 2007).

Table 2: Effect of bioinoculant (*NovoBac*) on Leaf Area Duration (Days) at different growth stages of chillies

Treatment	30-60 DAT	60-90 DAT	90-120 DAT	120- 150 DAT
T_1	39.45	54.23	58.69	61.29
T_2	44.31	61.02	68.40	76.22
T_3	42.77	58.76	64.71	68.91
T_4	43.37	60.21	67.53	75.15
T_5	40.43	54.99	60.63	64.01
T_6	40.79	56.43	63.81	68.28
T_7	43.64	60.41	68.58	76.50
T_8	44.76	63.03	72.92	82.04
T_9	44.49	62.01	70.64	77.67
T_{10}	46.62	65.15	74.72	82.92
Mean	**43.06**	**59.62**	**67.06**	**73.30**
SEd	**0.12**	**0.11**	**0.32**	**0.21**
CD (P:0.05)	**0.25**	**0.24**	**0.67**	**0.63**

Specific Leaf Weight (SLW): SLW indicates the quantity of metabolites (photosynthates) accumulated per unit leaf area and it is considered as a reliable index for improving yield of crops. The SLW increases significantly and the maximum value was found in T_{10} (*NovoBac* seed treatment 2g/kg + soil drenching @ 500 g ha^{-1} on 15 DAT) and the lowest value in T_1 (control) was observed (Table 3). *Bacillus* strains enhance SLW mainly by producing hormone like substances especially auxin. Since, auxin has been found to have established role in cell division and elongation which might have contributed for increased number of cells and facilitated the better stacking of the mesophyll cells leading to higher SLW. Rajmohan (1989) observed that the foliar feeding of NAA improved SLW in soybean.

Table 3: Effect of bioinoculant (*NovoBac*) on specific leaf weight (mg cm^{-2}) at different growth stages of chillies

Treatment	30DAT	60DAT	90DAT	120DAT	150DAT
T_1	0.226	0.350	0.537	0.637	0.248
T_2	0.287	0.466	0.736	0.910	0.313
T_3	0.283	0.450	0.699	0.815	0.303
T_4	0.283	0.456	0.732	0.825	0.311
T_5	0.265	0.436	0.681	0.766	0.301
T_6	0.273	0.441	0.695	0.767	0.303
T_7	0.295	0.482	0.741	0.933	0.313
T_8	0.333	0.546	0.931	0.973	0.380
T_9	0.326	0.530	0.817	0.938	0.344
T_{10}	0.351	0.594	0.976	1.116	0.399
Mean	**0.292**	**0.475**	**0.755**	**0.868**	**0.321**
SEd	**0.001**	**0.003**	**0.006**	**0.006**	**0.020**
CD (P:0.05)	**0.003**	**0.006**	**0.012**	**0.013**	**0.043**

Crop Growth Rate (CGR): CGR, the capacity of biomass production per unit ground area per unit time revealed significant influence of *NovoBac* treatments. An increase in crop growth rate was observed up to 60-90 DAT and a reduction thereafter can be seen in Table 4. The highest growth rate was observed in T_{10} followed by T_8 and the lowest value was observed in control. The CGR was found increased by 38 per cent in T_{10} when compared to control. This significant increase in CGR at 60-90 DAT might be due to the fast development of source as well as sink in chillies. Shibles and Weber (1996) observed a strong positive correlation between CGR and LAI in soybean. Maize plants treated with phosphate solubilizing bacteria, mycorrhizal fungi and 50 per cent triple super phosphate showed significant increase in CGR (Mehdi *et al.,* 2011). Similarly in the present study, data revealed that inoculation of *Bacillus* increase CGR at all the stages of observation.

Table 4: Effect of bioinoculant (*NovoBac*) on Crop Growth Rate (g m^{-2} day^{-1}) at different growth stages of chillies

Treatment	30-60 DAT	60-90 DAT	90-120 DAT	120- 150 DAT
T_1	0.356	0.403	0.378	0.239
T_2	0.435	0.540	0.515	0.376
T_3	0.384	0.467	0.442	0.303

Treatment	30-60 DAT	60-90 DAT	90-120 DAT	120- 150 DAT
T_4	0.385	0.499	0.474	0.335
T_5	0.374	0.431	0.406	0.267
T_6	0.376	0.446	0.421	0.282
T_7	0.442	0.549	0.524	0.385
T_8	0.528	0.556	0.531	0.392
T_9	0.501	0.553	0.528	0.390
T_{10}	0.562	0.560	0.535	0.396
Mean	**0.4342**	**0.5009**	**0.4756**	**0.3595**
SEd	**0.0035**	**0.0029**	**0.003**	**0.0077**
CD (P:0.05)	**0.0074**	**0.0060**	**0.007**	**0.0163**

Total dry matter production (TDMP): TDMP represents the direct relationship between photosynthesis and yield. All plants produce dry matter, but the efficient plants accumulate more dry matter by utilizing available resources. The plants which have high TDMP indirectly indicate its individual efficiency in that environment. The increase in TDMP with increase in number of days was observed in the present study. The maximum TDMP was observed in T_{10} (110.83) and the minimum in T_1 (65.82) on 150 DAT as observed (Table 5). This increase in dry matter production of inoculated plants may be attributed to enhanced nutrient uptake and improved root development. Similarly, Kyounga *et al.* (2010) and Ferreira *et al.* (2011) showed an increase in dry matter in chillies and lettuce.

Table 5: Effect of bioinoculant (*NovoBac*) on Total Dry Matter Production (g plant^{-1}) at different growth stages of chillies

Treatment	30DAT	60DAT	90DAT	120DAT	150DAT
T_1	30.51	44.80	55.90	62.15	75.82
T_2	39.53	56.79	79.33	91.94	95.68
T_3	39.00	51.85	70.49	77.83	95.11
T_4	39.46	54.65	76.37	91.70	95.20
T_5	31.20	46.62	64.38	69.09	77.89
T_6	38.14	50.43	64.86	69.12	92.37
T_7	40.53	58.07	80.44	93.12	96.82
T_8	43.66	66.22	88.32	99.98	104.10
T_9	42.64	62.56	82.54	97.99	100.99
T_{10}	44.68	69.70	91.97	107.16	110.83
Mean	**38.93**	**56.17**	**75.46**	**86.01**	**94.48**
SEd	**3.17**	**0.39**	**0.55**	**10.12**	**10.79**
CD (P:0.05)	**6.67**	**0.83**	**1.15**	**21.28**	**22.67**

Reference

[1] Amal G Ahmed, Salwa Orabi and Gomaa A M (2010) Bio-organic farming of grain sorghum and its effect on growth, physiological and yield parameters and antioxidant enzymes activity. Res J Agri Bio Sci 6(3): 270-279.

[2] Gomez K A and Gomez AA (1984) Statistical procedures for agricultural research. An IRRI book, Wiley Interscience Publication, John Wile and Sons, New York, USA.Pp.680.

[3] Hansen W R (1972) Net photosynthesis and evapo transpiration of field grown soybean canopies. Ph.D. Thesis of IOWA state, University library, Ames.

[4] Javier De Grazia, Pablo A. Tittonell, and Angel Chiesa (2007) The effect of substrates with compost and nitrogenous fertilization on photosynthesis, precocity and pepper (*Capsicum annuum*) yield. Cien Inv Agr 34(3): 151-160.

[5] Kyounga Kim, Woojong Yim, Pankaj Trivedi, Munusamy Madhaiyan, Hari P. Deka Boruah, Md. Rashedul Islam, Gillseung Lee and Tongmin Sa (2010) Synergistic effects of inoculating arbuscular mycorrhizal fungi and *Methylobacterium oryzae* strains on growth and nutrient uptake of red pepper (*Capsicum annuum* L.). Plant Soil 327:429–440.

[6] Mehdi Zarabi, Iraj Alahdadi, Gholam Abbas Akbari, and Gholam Ali Akbari (2011) A study on the effects of different biofertilizer combinations on yield, its components and growth indices of corn (*Zea mays* L.) under drought stress condition. African J Agri Res 6(3): 681-685.

[7] Pandey R K and Singh V B (1981) Influence of source and sink size on flower drop and seed yield of Pigeon pea. Indian J Agric Sci 51: 185-188.

[8] Pearce R B, Brown R H and Balaster R E (1968) Photosynthesis of alfalfa leaves as influenced by age and environment. Crop Sci 36: 677-680.

[9] Power J E, Wills W O, Granes D L and Reichman R A (1967) Effect of soil temperature, phosphorus and plant age on growth analysis of barley. Agron J 59: 231-234.

[10] Shibles R M and Weber C R (1966) Interception of solar radiation and dry matter production by various soybean. Crop Sci 5: 575-577.

[11] Tsai C T and Kuo C G (1984) Alternation by high temperature of auxin and gibberellin concentrations in the floral buds, flowers, and young fruit of tomato. Hortscience 19: 870–872.

[12] Watson D J (1956) Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. Ann Bot 11: 41-46.

[13] Wetblank P J, French SA W and Wittis J K (1966) Dependence of yield of wheat varieties on their leaf area duration. Ann Bot 30: 291-299.

[14] Williams R E (1946) The physiology of plant growth with special reference to the concept of NAR. Ann Bot 10: 41-71.