Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(2): 3037-3040
Received: 04-01-2018
Accepted: 05-02-2018

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Effect of different microbial strains on growth parameters *viz*. Lai, Cgr, Rgr and Nar of baby corn

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Abstract
A field experiment was conducted in 2014-15 and 2015-16 in rabi seasons at agricultural research farm of B.H.U. to study the effect of different strain of potassium solubilising bacterias and fungi in combination with various fertility levels on the microbial status and their corresponding impact on soil health. The trial consisting of *Agrobacterium*, *Flavobacterium*, *Rhizobium* and fungal strain of *Trichoderma* and four fertility levels was laid out in a split plot design with four replication by keeping fertility levels in the main plot and strains in the subplot. Significantly higher microbial population was recorded by the use of different microbes. Different physiological growth parameters such as LAI, CGR, RGR and NAR of baby corn crop were found to be the highest with 100%NPK+ *Agrobacterium sp*. and it was found to be at par with 100% NP+75%K + *Agrobacterium sp.* found to improve the crop growth under edaphic and climatic condition.

Keywords: microbial strains, parameters *viz, Agrobacterium, Flavobacterium, Rhizobium*

Introduction
The cultivation of baby corn is becoming popular among the growers in rural areas in recent years due to its diverse utility and high net returns (Verma *et al.* 2012) [10]. Adopting such crops, farmers were able to get higher economic return in short period as compared to traditional crops. Cost effective production and processing of baby corn may occupy an important place in the area of agri-business. India is emerging as one of the potential baby corn producing countries because of its low cost production technology as compared to other countries. In Varanasi region of Eastern Uttar Pradesh, baby corn is rather a new introduction and efforts are required to standardize and economize its cultivation.

Current soil management strategies are mainly dependent on inorganic chemical-based fertilizers, which cause a serious threat to soil health and environment. The exploitation of beneficial microbial strain as a biofertilizer has become of paramount importance in agriculture sector for their potential role in improving soil health and sustainable crop production. The eco-friendly approaches inspire a wide range of application of useful microscopic organisms leading to improved nutrient uptake (Datta *et al*., 2009) [9].

Microbial inoculants are organic products containing living cells of different types of micro-organism, which have the ability to convert nutritionally important elements from unavailable to available form through biological process (Vessey, 2003) [1]. Therefore, the inoculations with KSB and other useful microbial inoculants in the soil mandatorily restore and maintain the effective microbial population that solubilizes the chemically fixed form of potassium and made availability of other macro and micronutrients to enrich the soil fertility status (Pathak *et al*., 2009). The potassium solubilizing bacteria is a rhizospheric bacteria which solubilises the insoluble potassium (K) to soluble forms of K for plant growth and yield. The use of potassium solubilizing bacteria as a biological fertilizer was suggested as a solution to improve plant nutrition (Meena *et al*., 2014b) [2]. These KSB can help in enhancing the availability of nutrients playing an essential role in dynamic soil environment by contributing release of key nutrients from primary minerals and ores. These key macronutrients are central for nutrition of microbial population present in the soil and in turn also effectuate the benefit to plant nutritional status (Meena *et al*., 2014a) [3].

Trichoderma asperellum had the ability to promote plant growth through different mechanisms, such as solubilization of phosphates, potassium and minerals such as Fe, Mn and Mg that have important role in plant growth (Mastouri *et al.*, 2010) [4]. *Trichoderma* increases the rate of germination of maize and seedling growth of maize. A number of mechanisms for plant growth promotion by *Trichoderma* have been proposed (Harman *et al.*, 2004) [5].

Trichoderma promotes primary root length and root branching in maize by inducing lateral root growth (Bjorkman, 2004) [4]. Combination of *Trichoderma* inoculum and fertilizers performes better than single application of either fertilizer or inoculum. Wu *et al*. (2005) [7]. reported that the application of biofertilizer containing mycorrhizal fungus and three species of bacteria significantly increase the growth of maize.

Materials and Methods

The Agricultural Research Farm is situated at a distance of about 10 km from Varanasi Cant railway station. Flanked by left bank of the river Ganges it is situated at the Southern end of Varanasi city. Geographically the farm lies at 25^0 18'N latitude and 88^0 03'E longitude and at an altitude of 128.93 meters above the mean sea level. The experimental site was homogeneous in fertility with even topography, uniform textural make up having assured irrigation and other required facilities. Proper drainage facility was also available in order to remove the excess water if any, during the experimental period.The maximum temperature usually fluctuates between 23.2 ˚C to 42.8 ˚C while minimum temperature varies from 7.3 to 28.2 ˚C. occasionally extreme of minimum and maximum temperature variations are also realized. Total rainfall received during 2014-15 and 2015-16 was 1008.9 mm and 1248.3 mm, respectively which was 19.17% higher in 2015-16 than 2014-15. The weekly mean maximum relative humidity during the first experimental year (2014-15) ranged from 32 to 96 per cent with an average of 64 per cent and it ranged from 36 to 96 per cent during the crop cycle of baby corn. The weekly mean maximum relative humidity during the second year (2015-16), ranged from 26 to 94 per cent with an average of 60 per cent.

Experimental details

The experiment was laid out in a split plot design with 4 fertility levels (F_1, F_2, F_3 and F_4) in main plot and 4 strains (three bacterial strains of KSB i.e. S_1, S_2, S_3) and one fungal strain of *Trichoderma i.e.* (S_4) as a seed treatment in sub plot for baby corn. The experimental details were 100% NP+25% K (F_1), 100% NP+ 50% K (F_2), 100% NP+75% K (F_3) and 100% NPK (F_4) in the main plot and sub plot treatments (microbial strains) were *Agrobacterium sp.* (S_1), *Flavobacterium sp.* (S_2), *Rhizobium sp.* (S_3) and *Trichoderma sp.* (S_4). The potassium solubilising bacterial strains and fungal strain were applied as seed treatments. The seed was mixed with the broth culture of KSBs and *trichoderma* strains alongwith gum acacia for 6-8 hrs before sowing. Treatmentwise, the treated seeds were then used for sowing. 50 mL of each strain (broth culture) with 3 mL of gum acacia was applied for 5 kg seeds.

Leaf area index

The sources of the nutrient applied for N, P and K as per treatment were urea, DAP and MOP respectively. Half of the recommended dose of nitrogen and full doses of P, K and Zn were applied as basal and the one-fourth amount of nitrogen was top dressed through urea at tillering stage of the crop at optimum soil moisture condition and rest amount was applied at knee high stage. Growth parameter *viz.*, leaf area index (LAI) at 20,40,60,80 DAS and at harvest were recorded during both the years of experimentation.

Fertility level at 100%NPK (F_4) showed the maximum leaf area index in baby corn. 100%NPK (F_4) brought about significant increase in leaf area index over all other treatments except 100%NP+75%K (F_3) at 20, 40, 60 and 80 DAS of crop growth during 2014-15 and 2015-16. The lowest LAI was recorded with 100%NP+25%K (F_1). Significant improvement in leaf area index of baby corn was recorded with *Agrobacterium* (S_1) at all the crop growth stages and this was followed by *Trichoderma* (S_4) during both the years.

Table 1: Effect of KSBs and Trichoderma on leaf area Index (LAI) at different growth stages of baby corn.

Treatments	leaf area Index (LAI)									
	20 DAS		40DAS		60 DAS		80DAS		At harvest	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Fertility levels (RDF)										
F_1 (100%NP+25%K)	0.10	0.11	1.05	1.21	2.23	2.65	3.88	3.92	3.45	3.73
F_2 (100%NP+50%K)	0.13	0.14	1.16	1.23	3.11	3.43	4.95	5.05	4.67	4.84
F_3 (100%NP+75%K)	0.16	0.17	1.61	1.68	4.24	4.45	6.04	6.12	5.97	6.05
F_4 (100% NPK)	0.18	0.19	1.73	1.88	4.89	5.09	6.63	6.72	6.48	6.52
SEm±	0.01	0.01	0.05	0.09	0.24	0.32	0.27	0.31	0.28	0.31
C.D. (P=0.05)	0.03	0.03	0.15	0.27	0.73	1.01	0.81	0.95	0.86	0.95
Microbial strains										
S_1 (*Agrobacterium sp.*)	0.12	0.13	1.18	1.26	2.68	2.93	4.91	5.31	4.45	4.71
S_2 (*Flavobacterium sp.*)	0.11	0.12	0.98	0.99	1.70	1.79	3.79	4.13	3.43	3.77
S_3 (*Rhizobium sp.*)	0.12	0.12	1.00	1.04	1.87	1.99	4.08	4.42	3.73	3.92
S_4 (*Trichoderma sp.*)	0.12	0.13	1.03	1.09	2.14	2.34	4.34	4.71	3.97	4.21
SEm±	0.001	0.002	0.05	0.07	0.14	0.27	0.19	0.22	0.21	0.23
C.D.(P=0.05)	NS	NS	0.14	0.22	0.41	0.83	0.56	0.66	0.64	0.70

Crop growth rate (g day^{-1})

Observation on growth parameter *viz.* crop growth rate (g day^{-1}) at all the growth stages were recorded during both the years of experimentation. Fertility level at 100%NPK (F_4) showed the maximum leaf area index in baby corn. 100%NPK (F_4) brought about significant increase in crop growth rate (g day^{-1}) over all other treatments except 100%NP+75%K (F_3) at 20, 40, 60 and 80 DAS of crop growth during 2014-15 and 2015-16. The lowest LAI was recorded with 100%NP+25%K (F_1). Significant improvement in crop growth rate (g day^{-1}) of baby corn was recorded with *Agrobacterium* (S_1) at all the crop growth stages and this was followed by *Trichoderma* (S_4) during both the years.

Table 2: Effect of KSBs and Trichoderma on mean crop growth rate (g day^{-1}) at different growth stages of baby corn.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		At harvest	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Fertility levels (RDF)										
F1 (100%NP+25%K)	0.64	0.66	1.10	1.13	4.01	4.08	0.31	0.32	0.15	0.16
F2 (100%NP+50%K)	0.66	0.69	1.20	1.25	4.39	4.46	0.35	0.38	0.18	0.19
F3 (100%NP+75%)	0.69	0.73	1.32	1.36	4.75	4.86	0.41	0.42	0.21	0.231
F4 (100% NPK)	0.72	0.75	1.34	1.38	4.78	4.88	0.43	0.44	0.23	0.25
SE m+	0.01	0.01	0.03	0.03	0.08	0.09	0.02	0.02	0.01	0.01
C.D. (P=0.05)	0.03	0.04	0.08	0.09	0.23	0.27	0.05	0.06	0.03	0.04
Strains applied										
S_1 (*Agrobacterium sp.*)	0.71	0.73	1.34	1.38	4.72	4.79	0.40	0.43	0.21	0.23
S_2 (*Flavobacterium sp.*)	0.63	0.65	1.11	1.13	4.03	4.09	0.32	0.34	0.16	0.17
S_3 (*Rhizobium sp.*)	0.65	0.67	1.21	1.24	4.22	4.31	0.36	0.38	0.18	0.19
S_4 (*Trichoderma sp.*)	0.69	0.71	1.31	1.33	4.69	4.75	0.38	0.41	0.20	0.21
SE m+	0.01	0.02	0.04	0.05	0.04	0.04	0.01	0.02	0.01	0.01
C.D.(P=0.05)	0.02	0.05	0.11	0.14	0.11	0.12	0.04	0.05	0.03	0.03

Relative growth rate (g g^{-1} day^{-1})

Physiological growth parameter *viz.* relative growth rate (g g^{-1} day^{-1}) at 20,40,60,80 DAS and at harvest were recorded during both the years of experimentation. Fertility level at 100%NPK (F_4) showed the maximum relative growth rate (g g^{-1} day^{-1}) in baby corn. 100%NPK (F_4) brought about significant increase in relative growth rate (g g^{-1} day^{-1}) over all other treatments except 100%NP+75%K (F_3) at 20, 40, 60 and 80 DAS of crop growth during 2014-15 and 2015-16. The lowest LAI was recorded with 100%NP+25%K (F_1). Significant improvement in relative growth rate (g g^{-1} day^{-1}) of baby corn was recorded with *Agrobacterium* (S_1) at all the crop growth stages and this was followed by *Trichoderma* (S_4) during both the years.

Table 3: Effect of KSBs and Trichoderma on mean relative growth rate (g g^{-1} day^{-1}) at different growth stages of baby corn.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		At harvest	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Fertility levels (RDF)										
F1 (100%NP+25%K)	3.90	3.93	4.70	4.72	0.22	0.23	0.21	0.21	0.10	0.11
F2 (100%NP+50%K)	4.10	4.12	4.77	4.78	0.23	0.24	0.22	0.23	0.11	0.12
F3 (100%NP+75%)	4.20	4.24	4.84	4.86	0.24	0.25	0.22	0.23	0.12	0.13
F4 (100% NPK)	4.24	4.26	4.86	4.88	0.25	0.26	0.23	0.24	0.13	0.14
SE m+	0.04	0.05	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
C.D. (P=0.05)	0.12	0.16	0.07	0.08	0.04	0.04	0.03	0.03	0.02	0.02
Strains applied										
S_1 (*Agrobacterium sp.*)	4.19	4.21	4.79	4.83	0.24	0.24	0.22	0.22	0.12	0.13
S_2 (*Flavobacterium sp.*)	3.91	3.95	4.67	4.69	0.21	0.22	0.21	0.21	0.10	0.11
S_3 (*Rhizobium sp.*)	3.98	4.06	4.69	4.73	0.22	0.23	0.21	0.21	0.12	0.12
S_4 (*Trichoderma sp.*)	4.12	4.15	4.74	4.79	0.23	0.24	0.22	0.22	0.12	0.12
SE m+	0.03	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00
C.D.(P=0.05)	0. 10	0. 11	0.06	0.07	0.03	0.03	0.02	0.02	0.01	0.01

Net accumulation rate (x 10^{-3} gcm^{-2} day^{-1})

Growth parameter *viz.* net accumulation rate (g g^{-1} day^{-1}) at all the growth stages were recorded during both the years of experimentation. Fertility level at 100%NPK (F_4) showed the maximum net accumulation rate in baby corn. 100%NPK (F_4) brought about significant increase in net accumulation rate over all other treatments except 100%NP+75%K (F_3) at 20, 40, 60 and 80 DAS of crop growth during 2014-15 and 2015-16. The lowest LAI was recorded with 100%NP+25%K (F_1). Significant improvement in net accumulation rate of baby corn was recorded with *Agrobacterium* (S_1) at all the crop growth stages and this was followed by *Trichoderma* (S_4) during both the years

Table 4: Effect of KSBs and Trichoderma on mean net accumulation rate (x 10^{-3} gcm^{-2} day^{-1}) at different growth stages of baby corn.

Treatments	20 DAS		40 DAS		60 DAS		80 DAS		At harvest	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Fertility levels (RDF)										
F1 (100%NP+25%K)	0.51	0.52	0.58	0.59	0.70	0.71	0.88	0.89	0.05	0.06
F2 (100%NP+50%K)	0.53	0.54	0.60	0.61	0.71	0.71	0.94	0.95	0.07	0.07
F3 (100%NP+75%)	0.56	0.57	0.62	0.63	0.72	0.73	0.95	0.95	0.08	0.08
F4 (100% NPK)	0.57	0.57	0.64	0.65	0.73	0.74	0.97	0.99	0.09	0.10
SE m+	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.00	0.00
C.D. (P=0.05)	0.02	0.03	0.03	0.03	0.03	0.04	0.05	0.06	0.01	0.01
Strains applied										
S_1 (*Agrobacterium sp.*)	0.57	0.58	0.63	0.64	0.72	0.73	0.96	0.97	0.08	0.09
S_2 (*Flavobacterium sp.*)	0.51	0.52	0.57	0.58	0.69	0.70	0.87	0.89	0.05	0.05
S_3 (*Rhizobium sp.*)	0.54	0.55	0.59	0.60	0.70	0.71	0.90	0.91	0.06	0.06
S_4 (*Trichoderma sp.*)	0.56	0.57	0.61	0.62	0.71	0.72	0.93	0.94	0.07	0.07
SE m+	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
C.D.(P=0.05)	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.01	0.01

Result and discussion

Application of microbial strains had a positive role in influencing the physiological growth parameters *viz.* LAI, CGR, RGR and NAR of baby corn crop were found to be the highest with 100%NPK+ *Agrobacterium sp*. and it was found to be at par with 100% NP+75%K + *Agrobacterium sp.* followed by 100% NPK and *Trichoderma sp*. found to improve the crop growth more in the second year in comparison to first year. The application of fertiliser along with microbial strains (KSB) and *Trichoderma* found to enhance crop growth [Salem, (2000) and Kumar *et al*., (2015)] [12, 11].

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