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Contents

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Editorial Note

Ramesh Chandra
Editor in Chief

Indian agriculture has witnessed record food production of 257 million tonnes in past year through concerted efforts of our planners, scientists and farmers. This increase in food production in the country was mainly due to development of high yielding diseases and pest resistant crop varieties, increase in the irrigated area and pesticides and fertilizer consumption. However, the maintenance of food and environmental security is a great challenge for all of us in the years ahead in the scenario of shrinkage in land area under cultivation and changing climate. Soil, a precious gift of nature to humankind, is reducing per person posing the challenge of maintaining the soil health to produce more and more from less and less area to meet the food demand of burgeoning population in the country. Agricultural technologies that led to green revolution in the country resulted in the degradation of soil resource owing to its overexploitation under intensive cropping coupled with mismanagement. Land degradation is causing a heavy toll of soil resources every year. Estimates indicated 187.8 M ha of degraded land to various degrees through different degrading processes in India. Degradation of agricultural land has become a great cause of concern during the 21st century and will remain high in the next century because of its direct impact on agricultural sustainability and food security. The soil quality has undergone a serious damage leading to a decline in crop production and factor productivity. Large scale deficiency of secondary and micronutrients are showing up in different areas in addition to deterioration of soil structure and loss in soil organic matter and biodiversity. It emphasized the urgent need to study the soils of different regions for suggesting specific management strategies for obtaining sustainable production.

It is now widely accepted that future of food, livelihood and environmental security depends upon the appropriate management of natural resources such as soil, water, weather, biodiversity etc. Considerable new information is being generated by the researchers on soils and their management for enhancing food production in the country. Many a time these researchers do not find appropriate platform to share their findings and views with other researchers and stakeholders. This is what formed the basis of publishing this new periodical, *Indian Journal of Plant and Soil Science*. I am confident that with the support of scientific community engaged in soil and plant research, it will serve the need of the nation in managing the soil resource and environmental quality while achieving sustainable food production.

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Original Article

Inoculation Effect of *Mesorhizobium ciceri* and Rhizospheric Bacteria On Nodulation and Productivity of Chickpea (*Cicer arietinum* L.) and Soil Health

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Abstract

A field experiment was carried out at Pantnagar during 2005-06 to examine the interaction between 10 rhizospheric bacteria isolates with *Mesorhizobium ciceri* on nodulation, growth, yields and nutrient uptake by chickpea (*Cicer arietinum* L.). The experimental soil was sandy loam of pH 7.2 having 5.2 mg/kg Organic C, 140.2 kg/ha available N, 16.1 kg/ha available P and 282.5 kg/ha available K. The test crop variety was Pant G-186. Inoculated *Mesorhizobium* sp. alone, irrespective of rhizobacteria, increased the number and dry weight of root nodules numerically, by 23.2 and 23.1 % and plant dry weight significantly, by 3.2 % over uninoculated control at 60 DAS. It also gave numerical increases of 11.2 % and 13.0 % in grain and straw yields, 26.1 and 29.8 % in N uptake and 21.2 and 30.3 % in P uptake by grain and straw, respectively. Different rhizobacteria, irrespective of *Mesorhizobium* sp., gave increases of 77.2 to 58.7 % in nodule number and 13.3 to 65. % in nodule dry weight at 60 DAS, 20.0 to 57.7 % in grain yield, 12.9 to 44.1 % in straw yield, 17.8 to 85.4 % in N uptake by grain, 15.0 to 46.6 % in N uptake by straw, 5.5 to 63.8 % in P uptake by grain and 14.8 to 61.9 % in P uptake by straw over no rhizobacteria inoculation. All rhizospheric bacteria, except LK-754, LK-786, PUK-791 and KB-133 improved the grain and straw yields significantly. All rhizospheric bacteria, except LK-754, also recorded significantly more microbial biomass C, dehydrogenases activity and acid phospahatase activity in soil over no rhizobacteria inoculation. Interaction between the *Mesorhizobium* sp. and rhizobacteria with was not significant. PUK-171 was found to be the best for most plant growth and yield and soil health parameters.

Keyswords

Mesorhizobium; Rhizobacteria; Microbial biomass carbon.

Introduction

Chickpea is major pulse crop of India accounting for 35% area and 45% of total production of pulses. India also has the distinction of being the top producer of chickpea in the world accounting for 71.51 % of the global output. It has been an integral part of Indian agriculture since time immemorial because of its intrinsic ability of nitrogen fixation and adaptation to diverse agro- ecological conditions. The current productivity of chickpea of 943 kg/ha in the country is relatively low because of its cultivation on marginal soils without adequate inputs management including plant nutrients. Being leguminous crop, chickpea has inherent capacity of atmospheric nitrogen fixation in association with rhizobia. Although, native soil rhizobia are capable of interacting and nodulating the chickpea to varying extent depending upon the genotypes, soil and crop management practices, there is need to develop an efficient symbiosis of host specific rhizobial isolates and

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also to develop isolates with superior nodulation competitiveness that can overcome the limitations of low nitrogen fixation, poor crop yield, and lower effectiveness under field conditions.[1]

The rhizospheric microorganisms not only influence the inoculated rhizobia adversely through saprophytic competition, but also help them in survival through synergistic interactions resulting in an increase in their nodulation efficiency. Co-inoculation of rhizobacteria with rhizobia have been found to increase nodulation, N_2 fixing efficiency, growth and yield of several pulse crops in laboratory and field conditions.[2-4] Several mechanisms such as alteration in the composition of rhizospheric microorganisms, production of plant signaling compounds, bacteriocins, siderophores, plant growth hormones and improving availability of nutrients by rhizospheric microorganisms have been reported for such synergism.[5] However, compatibility of these microorganisms needs to be evaluated because of the possibility of antagonistic interactions among them. Improving symbiotic N_2 fixation efficiency using synergistic rhizobacteria appears to be a cost effective and eco-friendly technology of increasing the pulse production, would lessen the need of fertilizer and decrease energy input. Keeping this in view, the present investigation was conducted to examine the effect of seed inoculation of rhizospheric bacteria and rhizobia in chickpea on root nodulation, plant dry matter, yields, nutrient uptake, residual soil nutrients and soil biological properties under field conditions.

Materials and Methods

Microbial Cultures

Effective strains of *Mesohizobium* sp. *Cicer* (strain LN 7007) was obtained from department of Microbiology, CCSHAU, Hisar and 10 rhizobacteia LK-786 (*Kurthia* sp.), LK-884 (*Pseudomonas* sp.), PUK-46B6 (*Pseudomonas diminuta)*, PUK-171(*Klebsiella* sp.), CRB-2 (*Pseudomonas* sp.), KB-133 (*Pseudomonas* sp.), LK-822, LK-373, LK-754, PUK-791 (unidentified) were obtained from Department of Soil Science of the University. The purity of the cultures was checked with routine microbiological techniques. The obtained *Mesorhizobium* sp. was multiplied in YEM broth for 4 days and rhizobacteria in succinate broth for 2 days and mixed with sterilized charcoal, neutralized with 12.5 % $CaCO_3$, in 1:2 ratio separately to prepare their carrier based inoculants.

Field Study

The efficiency of the rhizobacteria in terms of nodulation, growth and yield of chickpea and soil health was evaluated in a field study during *Rabi* 2005-06 at Crop Research Centre of the G. B. Pant University of Agriculture and Technology, Pantnagar. The soil was sandy loam of pH 7.2 having 5.2 g/kg Organic C and 140.2, 16.1, 282.5 kg/ha available N, P and K, respectively. Treatments consisting of inoculation with 10 rhizobacteria, alone and with *Rhizobium* sp., along with 20 Kg N + 40 Kg P_2O_5/ha and an uninoculated control were laid out following two factorial experiment in Randomized Block Design in plots of 2.4 m × 3.0 m size in 3 replications. Chickpea seed (cv. Pant G 186) was treated with the required inoculants of *Mesohizobium* sp. and rhizobacteria @ 20 g inoculant /kg seed at the time of sowing. Crop was raised as per the recommended agronomic practices. Five plants from the each plot were randomly uprooted along with a soil core at 60 days after sowing (DAS). Soil cores with plants were placed in sieve and roots were washed off with water jet to remove the adhering soil. Nodules were removed from the roots and counted. Dry weights of nodules and plants were determined after drying in hot air oven at 70 ^{o}C to constant weight. Grain and straw yields were recorded at final harvest. N and P concentrations in grain and straw were determined after grinding the samples to 40 mesh. N contents was determined by micro-Kjeldahl method and P after wet digestion in tri-acid mixture (HNO_3 : H_2SO_4 : $HClO_4$ in 9:4:1 ratio) by vanadomolybdophoshporic yellow colour methods [6] and N and P uptake by grain and straw were calculated.

Soil Studies

Soil samples were collected, in duplicate, from individual plot after harvesting the crop. One soil sample of each plot was air-dried, processed to pass through 2 mm sieve and analysed for available N (0.32% alkaline $KMnO_4$ oxidizable) and available P (0.5 M $NaHCO_3$ extractable) following the methods described by Page.[6] Another soil sample was stored at low temperature in a deep freeze and used for estimation of different soil biological properties. Microbial biomass carbon in soil samples was estimated by chloroform fumigation extraction method of Jenkinson and Powlson[7] using Kc value of 0.45.[8] Soil dehydrogenase activity was estimated by reduction of 2,3,5 triphenyl tetrazolium chloride to triphenyl formazan (TPF) by the methods of Tabatabai [9] and acid and alkaline phosphatase activities by incubating with buffered p-nitrophenyl phosphate following method of Tabatabai and Bremner.[10] The treatments were compared using the F-test by calculating the critical difference at 5% level of significance.

Results and Discussion

Nodulation

Seed inoculation with *Mesohizobium* sp., irrespective of rhizobacteria, gave numerical increases of 21.6 and 23.1 % in number and dry weight of root nodules over no inoculation treatment at 60 DAS, respectively (Table 1). Such favourable effects of *Rhizobium* inoculation on nodulation in chickpea have also been reported by Gupta [11] and may be due to either presence of sufficient native rhizobia nodulating the crop or presence of large but ineffective population that gave strong competition to the inoculated rhizobia in root colonization and infection. Different rhizobacteria, irrespective of *Mesorhizobium* sp., showed increases ranging from 7.2 to 58.7% in nodule number and 13.3 to 65.6 % in nodule dry weight over no rhizobacteria treatment. All rhizobacteria, except LK-822, PUK-791, indicated significant increases in both nodule number and nodule dry weight over no rhizobateria inoculation treatment. PUK-171 by producing the highest number and dry weight of nodules was significantly superior to all other rhizobacteria and fertilizer treatment. Such variation in the efficiency of rhizobacteria have also been reported by Chandra and Pareek [12] in lentil and urdbean and Gupta [11] in mungbean due their different genetic make up and biochemical functions.

Plant Dry Matter

Averaged over different rhizobacteria treatments, *Mesohizobium* sp., showed significant improvement in plant dry matter of 3.2 % over no inoculation at 60 DAS. (Table 1). The results corroborates with findings of Gupta who also found significant improvement in chickpea plant dry matter due to *Mesohizobium* sp. inoculation.[13] The inoculated rhizobacteria also favoured the plant dry matter registering significant increases of 7.5, 11.2 and 7.2 % with LK-82, PUK-171 and PUK-791, highest being with PUK-171. Similar positive effects of rhizospheric bacteria on plant growth have also been reported by Gupta [11] in chickpea and Tilak *et al*.[4] in pigeonpea due to enhanced N_2 fixation, secretion of plant growth promotory substances, solubilization of P leading to its more availability, suppression of diseases etc.

Productivity

Inoculation of *Mesohizobium* sp. indicated non-significant increases of 167 and 234 kg/ ha in grain and straw yields over no inoculation treatment (Table 1). This could be viewed in the light of earlier observations of marginal effect of *Mesohizobium* sp. inoculation on nodulation. However, the inoculated rhizobacteria recorded significant increases of 20.0 to 57.7 % in grain yield and 12.9 to 44.1 % in straw yield, irrespective of *Mesorhizobium* sp. inoculation. PUK-171 by producing the highest grain and straw yields was significantly superior to all other treatments in grain and straw yield production. The results are in agreement with reports of Chandra and Pareek [12] in urdbean and mungbean and Khanna *et al* [14] in lentil. It could be attributed to enhancement in nodulation and N_2 fixation.Interactions between inoculated

Table 1: Effect of *Mesorhizobium* sp. and rhizobacteria inoculation on chickpea root nodulation and plant dry matter at 60 DAS and productivity

Treatment	Nodule number /plant	Nodule dry weight (mg/plant)	Plant dry weight (g/plant)	Yield (kg/ha)	
				Grain	Straw
No *Mesorhizobium* sp.	11.2	958	3.80	1493	1800
Mesorhizobium sp.	13.8	1180	3.92	1660	2034
C.D. at 5 %	NS	NS	0.08	NS	NS
No Rhizobacteia	9.7	803	3.75	1292	1591
20 kg N + 40 kg P_2O_5/ha	12.6	1108	3.94	1451	1822
LK-373	12.0	1037	3.75	1551	1906
LK-754	13.4	1169	3.69	1322	1798
LK-786	13.4	1148	3.61	1433	1573
LK-822	11.8	974	3.86	1603	1936
LK-884	12.7	1030	4.03	1924	2152
PUK-46B6	13.3	1121	3.77	1598	1998
PUK-171	15.4	1330	4.17	2038	2294
PUK-791	10.4	915	4.02	1545	1814
CRB-2	12.6	1073	3.87	1700	2236
KB-133	13.0	1141	3.85	1468	1878
C.D. at 5 %	1.2	149	0.23	224	276

Table 2: Effect of *Mesorhizobium* sp. and rhizobacteria inoculation on nutrient uptake by chickpea

Treatment	N uptake (kg/ha)		P uptake (kg/ha)	
	Grain	Straw	Grain	Straw
No *Mesorhizobium* sp.	53.1	13.2	5.99	4.29
Mesorhizobium sp.	67.0	17.1	7.26	5.59
C.D. at 5 %	NS	NS	NS	NS
No Rhizobacteia	46.7	13.3	5.26	3.84
20 kg N + 40 kg P_2O_5/ha	57.9	13.5	5.74	4.13
LK-373	58.3	16.7	6.38	4.41
LK-754	50.5	16.3	5.55	4.73
LK-786	50.7	13.3	5.91	4.11
LK-822	62.6	13.8	6.88	4.74
LK-884	66.5	17.8	8.50	6.22
PUK-46B6	57.9	15.3	6.54	5.24
PUK-171	86.6	18.7	9.09	6.11
PUK-791	55.9	12.9	6.48	4.96
CRB-2	63.8	16.3	6.87	5.93
KB-133	60.4	15.7	6.28	4.69
C.D. at 5 %	10.9	2.7	0.92	0.79

Mesohizobium sp. and rhizobacteria were non-significant for all the studied parameters.

Nutrient Uptake

Averaged over different inoculated rhizobacteria, *Mesohizobium* sp. inoculation recorded only numerical increases of 26.2 and 29.5 % in N uptake and 21.2 and 30.3 % in P uptake by grain and straw, respectively. The rhizobacteria registered increases from 17.8 to 85.4 % and 15.0 to 46.6 % in N uptake and 5.5 to 63.8 % and 14.8 to 61.9 % in P uptake by grain and straw, respectively, over no rhizobacteria inoculation. Rhizobacteia LK 884, PUK-171 and CRB-2 indicated significant increases in N uptake by both grain and straw. Similarly, LK-822, LK 884, PUK-46B6, PUK-171 and PUK-791 recorded significantly more P uptake by both grain and straw. The highest N and P accumulation in grain and P accumulation in straw was obtained with PUK-171. Such

Table 3: Effect of *Mesorhizobium* sp. and rhizobacteria inoculation on soil properties after chickpea harvesting

Treatment	Available nutrients (kg/ha)		Microbial biomass C (µg/g soil)	DHA (µg TPF/g soil/24 h)	Phosphomonoesterase activity (µg PNP / g soil/h)	
	N	P			acid	alkaline
No *Mesorhizobium* sp.	215.0	20.5	317.1	115.2	145.2	34.9
Mesorhizobium sp.	230.8	20.7	359.7	122.2	155.0	42.7
C.D. at 5 %	NS	NS	NS	4.9	NS	NS
No Rhizobacteia	159.9	16.2	263.6	96.7	128.6	32.3
20 kg N + 40 kg P_2O_5/ha	271.9	20.7	306.1	112.6	146.1	34.4
LK-373	183.7	20.0	321.0	112.3	146.8	37.4
LK-754	192.8	19.9	294.0	102.5	129.9	30.4
LK-786	213.6	20.8	325.1	102.5	148.9	31.6
LK-822	233.2	21.1	350.3	121.6	154.0	34.8
LK-884	298.3	21.4	417.9	155.5	171.4	57.3
PUK-46B6	204.9	21.1	339.4	122.1	146.7	36.9
PUK-171	269.7	21.7	429.8	137.4	176.3	64.1
PUK-791	201.3	21.5	326.3	118.4	147.3	33.1
CRB-2	242.5	21.4	365.7	129.3	158.1	40.3
KB-133	203.3	21.1	321.5	112.2	147.3	32.6
C.D. at 5 %	18.2	1.88	50.4	12.1	3.1	2.9

DHA, Dehydrogenase activity

variable effects of rhizospheric bacteria in N and P accumulation by crops have also been reported by Gupta *et al* [3] in greengram and attributed to their positive effects on nodulation and N_2 fixation and P solubilization in soil. *Mesorhizobium* sp. did not show significant interaction with rhizospheric bacteria in N and P uptake by chickpea.

Soil Properties

Available N and P in soil after crop harvesting improved numerically due to *Mesorhizobium* sp. inoculation, irrespective of rhizospheric bacteria inoculation, which could be explained in view of non-significant improvement in nodulation by *Mesorhizobium* sp. inoculation (Table 3). All the inoculated rhizospheric bacteria resulted in significantly more available N, by 14.8 to 86.6 %, and available P, by 22.8 to 33.9 %, over no rhizobacteria inoculation. The highest available N in soil was recorded with LK-884, which was significantly better than all other rhizobacteria. The highest available P in soil was found with PUK-171, however, it was statistically comparable to all other rhizospheric bacteria. The increase in available N in soil may be attributed to improvement in nodulation and N_2 fixation following rhizobacteria inoculation due to their synergistic interaction with native as well as inoculated rhizobia nodulating chickpea [10] while an increase in available P may be due to P solubilization activity of the inoculated rhizobacteria. Soil microbial biomass C after crop harvesting reflected the trend that observed in soil available N. All the rhizospheric bacteria, except LK-754, registered significantly more microbial biomass C in soil of 12.8 to 63.1 % than no rhizobacteria inoculation, highest being with PUK 171. The latter rhizobacteria was statistically comparable to LK-884, which gave maximum available N in soil. Microbial biomass is most labile pool of soil N and has positive correlation with available N in soil.[15] The differences in soil microbial biomass C under different treatments could be due to variation in crop growth, biomass production and rhizodeposition. A part of crop biomass returns to soil through leaf fall, influences availability of organic substrates for microorganisms causing variations in microbial biomass. The activity of dehdrogenase enzyme in soil represents the total metabolic activity of soil. The various rhizospheric bacteria, except LK-754, gave

significantly more DHA than no inoculation. It may be viewed in the light of microbial biomass C in soil. The different rhizobacteria, except LK-754, recoded significantly more acid phosphatase activities than no inoculation, but only LK 373, LK-884, PUK-46B6, PUK-171 and CRB-2 registered significantly more alkaline phosphatases activities in soil. Phosphates activities in soil are related with P minerlization and such variations due to inoculation of rhizobacteria have been reported earlier.[16] None of the studied soil parameter showed significant interaction between inoculated *Mesorhizobium* sp. and rhizospheric bacteria.

It could be concluded that rhizospheric bacteria had varying potential to enhance the nodulation and productivity of chickpea. Among different rhizobacteria, PUK-171 was found most efficient in improving yields of chickpea and soil health. Further, it is necessary to identify the rhzobacteria having synergistic interactions with *Mesohizobium ciceri* for harnessing their benefits in co-inoculation.

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Original Article

Climate versus Productivity

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Abstract

The relation between climate and agricultural productivity starts from that of carbohydrates dependent on photosynthetic activity and as such any relation between climate and productivity is primarily linked to the relation between photosynthetic yield and the climatic parameters This is the essence of Devanathan 'concept on the relation between climate and productivity On this basis productivity model has been developed and presented. This has been so widely tested by Ranganathan in tea and other crops in India and Sri Lanka as Consultant to IMT technologies Ltd., Pune.

Keyswords

Climate; Agricultural productivity; Photosynthetic activity.

Introduction

The important considerations deciding the relation between climate and productivity are:

1 Carbohydrate yield – function of photosynthesis

2 Bio-mass conversion and expression in terms of growth and recognition of time lag between carbohydrate production and expression of it in growth.

Devanathan's[1] concept and improvements there on by Ranganathan lead to generalized model for growth as given below:[2]

PART - A

The plant factors relating to water resistance to transportation mechanisms and evapo - transpiration to dissipate heat and adaptations to drought resistance are included in constant 'K 'along with the effects of crop husbandry practices which finally express themselves in terms of harvest index.

Soil Factors Relate to it

1. It's capacity to store water and supply it to plants
2. The path ways and the rates of repletion through rain fall and ,or irrigation against depletion through evapo-transpiration and plant uptake
3. Depletion/Repletion Pattern

Water Storage is Determined by

1. Soil structure expressed in terms of porosity (around 60 %) and bulk density (around 1.1) – the water held in micro-pores sustained by humic acids binding, and aeration, permeability and bio- activity maintained by meso and macro pores sustained by calcium aggregation and mechanical

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Generalized Model for Growth

Agro-climatic Potential φ = $\frac{Ft * R * (S+1)}{A} * \frac{R * T}{B} * \frac{K}{C}$

A -Photosynthetic yield

Ft-Temperature coefficient of photosynthetic process(Baldry, Buckeland Walker, 1966 Table-1) based on the rates of photosynthesis on isolated chloroplasts under saturated light and unlimited supply and moisture using labeled carbon under ideal conditions

R – Rainfall /irrigation efficiency factor (discussed in detail below in PART-A) Represents the probability of the length duration ,the water supply system maintains leaf water potential at and above critical level (88 % of the optimum level) during illumination

S+1 - Sunshine hours per day above limiting light saturation ; correction given for diffused light and unrecorded sun shine at boundaries at critical light saturation by adding +1

B- Bio-mass production and expression in terms of growth

Utilization of carbohydrates for biomass production interms of growth ,all reactions taking place in water medium The entire gamut of bio- chemical reactions involved are water and temperature dependent

R- Rainfall /irrigation water use efficiency or water use efficiency

T- temperature use efficiency –Effective use of available day degrees for growth (discussed in part-B)

C -Plantfactors and agronomic practices

Variations in transport mechanisms of carbon-di-oxide to mesophyll cells, transport resistance to water and , photosynthetic sites per unit area etc, and finally manifest in practical terms as HARVEST INDEX

Table1: Rates of Photosynthesis at Various Temperatures Relative to 25 p c (after Baldry, *et al* 1966) at Unlimited Supply of Carbon-di-oxide and Water 'Devanathan MA.W. (1976). The Quantification of Climatic Constraints on Plant Growth (Tea Quarterly 45: 43-72.)

t°c	Ft	t°c	Ft	t°c	Ft	t°c	Ft
0	3.4	10	31.1	20	75.4	30	126.8
1	4,5	11	35.2	21	80.4	31	132.9
2	5.0	12	39.8	22	85.1	32	138.9
3	7.6	13	44.3	23	90.1	33	145.0
4	9.9	14	48.8	24	94.9	34	151.2
5	12.3	15	53.0	25	100.0	35	157.7
6	15.2	16	57.5	26	105.0		
7	18.9	17	62.2	27	110.1		
8	22.6	18	66.7	28	115.1		
9	26.7	19	71.2	29	120.9		
t°c	temperature	Ft	Relative rate of photosynthesis				

composition of soils (texture).

2. Soil depth – for effective root penetration and volume of storage medium.

Water Storage Available to Plants is Calculated as Follows :

1. Soil depth : It is taken as the depth of the soil up to which 90 % of the root distribution is seen
2. Moisture at 1/3 atmospheres or 60 to 70 % of Water holding capacity is taken as available water for plants
3. Efficiency of moisture utilization is 100 % at top one third Soil depth and 50% at lower two thirds of soil depth or 70 % on an average

The Water Storage at any Given Time Units (Say Month) is Equal to:

F# = Fm +Rm – Etmwhere

'Fm' is the storage of water at the beginning of the month'.

1. 'Rm' the rain fall or quantum of irrigation for the month, 'Etm' the evapo -transpiration losses for the month.
2. 'F#' is the available moisture for the month.
3. 'Fm' at the beginning of the time unit is the 'F#' calculated at the end of previous time segment or 'F', the water storage capacity of the soil whichever is lower, or in other words 'Fm' is limited to maximum of 'F' values.

$R = 1 - e^{-(Fm + Rm - ET)/F}$

Where 'R' is the probability of leaf water potential maintained at or above critical level and represents rain fall or irrigation use efficiency.

PART – B

Growth is a function of transpiration (250 kg of water is transpired to manufacture one kg of biomass) and temperature. Water available is determined by depletion /repletion balance of water storage system. Hence it is represented by 'R' rain fall / irrigation water use efficiency factor.

All reactions are temperature dependent. Night temperature below 14 ^{0}C retards growth and the probability of number of days with night temperature falling below 14 ^{0}C is related to daily mean temperatures

Day degrees above the critical minimum temperature for growth i.e., 12.5 ^{0}C for tea determines the rate of biomass production for growth ; but the increase is exponential reaching a maximum value around 28 ^{0}C because losses due to respiration increases at a much faster rate than the gains through photosynthesis at temperatures above 30 ^{0}C

Hence the effect of temperature is given as below:

$T = 1 - e^{-(12.5 - t')/17.5}$

Where 12.5 is the minimum critical temperature for growth, t' is the mean temperature and 17.5 is the day degrees between the minimum critical temperature for growth and the temperature above which the net photosynthesis falls rapidly (that is 30 ^{0}C)

Other considerations

1. Time lag between photosynthetic yield and expression in terms of growth is about 5 weeks in the pruned year and 4 weeks in other years. To-day's crop is a reflection of photosynthetic yield obtained 4 to 5 weeks ago and the prevailing growing condition .
2. Hence, φ_p Agro- climatic potential of the previous month and ' φ_c' agro climatic potential of the current month are taken for correlating with yield. Prediction value is 94 % with Malawi data under constant management and non limiting fertilizer management ; 85 % with Sri Lankan Data with good distribution of rain water; and 70 % in South India with data involving wide variety of management practices and climatic Zones
3. Theoretically yield is represented by:

$Y = (k_1 * \varphi_p + k_2 * \varphi_c) CF$

Where k_1 and k_2 are relative contribution of φ_p and φ_c for the current crop; CF is the

Table 2: Water storage available to plants in different regions

	NE India	S India	Sri Lanka
Soil depth (90% root distribution),	75 cm	150 cm	150 cm
Water holding capacity	45 %	48 %	45 %
Bulk density of the soil	1.20	1.05	1.10
Water storage capacity (as rainfall equivalent)	20 cm	36 cm	36 cm
Evapo-transpiration cm /month	7-14	6-9	7-10
Drought tolerance	1-2 months	3-6 months	3-6 months

Table 3: Agro- Climate of some tea growing areas

AREA	t' ° C	RF cm	SS,h	ft	R	T	φ_p
Anamallais, SI	20.3	400	5.2	0.77	0.73	0.36	0.83
N.Wynaad	21.8	201	6.4	0.84	0.69	0.41	1.24
Vandiperiyar	22.4	211	6.4	0.88	0.66	0.44	1.14
Assam	23.4	206	5.6	0.93	0.69	0.44	1.29
Malawi	21.8	177	6.7	0.85	0.65	0.41	1.13
KANDY	23.5	164	6.8	0.93	0.66	0.47	1.26

correction factor which is related to 'harvest index' and factors influencing it.Agro- Climate of some tea growing areas are given in Table 3.

Acknowledgments

But for the support of late Mr CB Sharma Chairman & Managing Dtrectorof M/s Ram Bahadur Thakur Ltd., Cochin and Dr, SS Ranade, Chairman and Managing Director of IMT Technologies Ltd., I could not have accomplished this study. I am grateful to them for supporting me after my retirement from United Planters' Association of Southern India.

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Original Article

In-Vitro Callus Induction and Shoot Regeneration in *Justica adathoda* (L.): Potent Indian Medicinal Plant

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Abstract

Not provided.

Keywords

Justica adathoda;Tissue culture;Medicinal plant

Introduction

In vitro propagation is an important tool for rapid multiplication of medicinal plants [1] as well as for the extraction of active ingredients. *Justica adathoda* (L) commonly known as Adhathodai in ayurveda belongs to the family Acanthaceae. It is small clambering vine, leaves small, cordate, apex acuminate, corolla composed of fully fused petals, white colored, annual plant. Prefers western gatz, fences or low ground cover as a substrate. The leaves collected from wild are eaten as a cooked vegetable in Kenya and added to soup in Nigeria. Ayurveda has identified many medicinal properties of this plant and it is effectively used against dysentery [2,3] choosy leaves with alcohol are applied to open sores and pustules. A paste of leaves is applied on throat infection, respiratory problems and bronchial asthma. Flower are used as cleaning agents to improve difficult breathing, relive pain and to improve vision. It is being used as an antioxidant. The plants of this family are extensively investigated as a newer source of natural antioxidants and for other bioactive compounds of human benefits.[4] Due to its seasonal availability and endemic distribution the present investigation was focused on to obtain callus from leaves, node and bud. The *in-vitro* multiplication may benefit as the perennial source for the isolation of bioactive compounds.

Materials and Methods

Plant Material

Healthy plant of *Justica adathoda* (L.) was collected from Western gatz, Suruli falls, Theni, Tamil nadu, India. The different parts of plants like leaves, node and bud were washed with tap water and then with detergent (Teepol) for 15 min followed by washing with distilled water.

Preparation of Explants

Leaf as Explants: The leaf explants were cut into small pieces and washed with running water. Then, the explants were surface-sterilized with 0.1% (w/v) mercuric chloride for 2-3 min, followed by 70% ethyl alcohol 2-3 min, washed 3-4 times with sterile double-distilled water and inoculated on agar-solidified MS (Murashige & Skoog) medium supplemented with different concentrations of 2,4-D, kinetin and BAP, either alone or in combination, with 3% (w/v) sucrose. The pH of the medium is adjusted to 5.8 before sterilization. Cultures were maintained at 27±1°C photoperiod.

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Node as Explants: Nodal region was surface sterilized (similar to leaves) with 0.1% mercuric chloride and 70% ethyl alcohol and cultured on agar solidified MS medium supplemented with different various combinations and concentrations of Auxins 2,4 D (0.1-0.8 mg/L), NAA (0.2,0.4 and 0.8 mg/L) and cytokines kinetin (0.1-0.8 mg/L), or BAP (0.2 mg/L) with 3% (w/v) sucrose. The pH of the medium was adjusted to 5.8 before sterilization. Cultures were maintained at 27±1°C photoperiod.

Bud Explants: Bud explants were surface-sterilized with 0.1% (w/v) mercuric chloride for 2-3 min, followed by 70% ethyl alcohol 2-3 min, then washed 3-4 times with sterile double-distilled water and inoculated on agar-solidified MS medium supplemented with different combinations and concentrations of auxins 2,4 D (0.1-0.8 mg/L), NAA (0.2,0.4 and 0.8 mg/L) and cytokines kinetin (0.1-0.8 mg/L), or BAP (0.2 mg/L) with 3% (w/v) sucrose. The pH of the medium was adjusted to 5.8 before sterilization. Cultures were maintained at 27±1°C photoperiod.The experiment was terminated after an interval of 30 days. In another set of experiments where the shoot regeneration capacity was determined, for this node explants was inoculated in the tubes containing MS medium supplemented with kinetin and NAA in concentrations. At least 10 tubes were inoculated and incubated under optimal condition as defined above. After 30 days, the experiment was terminated and shoot generation capacity, its length and morphology were recorded.

Shoot Culture

Basal medium used for initial set of experiment for shoot proliferation consisted of MS salt 3% (w/v) sucrose, and 0.9% (w/v) agar. The pH of medium was adjusted to 5.7. The basal medium was supplemented with various combinations of auxins (NAA, 2,4-D) with cytokines (Kinetin, BAP) at different concentration. The cultures were incubated at 27 ± 1^{o}C under 16 hr photoperiod with cool white fluorescent light.

Results and Discussion

Callus Induction: All the combinations of NAA, 2, 4-D with kinetin and BAP produced callus (Table 1&2). Optimum concentration of auxins and cytokines which initiated callus with high percentage of response was used for further study. Callus induction was different in different explant with different hormone concentrations. The highest response of callus formation in leaves (94.3±2.54 %) was observed in MS medium supplemented with 0.8 mg/L 2,4-D plus 0.8mg/L kinetin which resulted in white soft callus. The combination of NAA (95.6±0.96% 0.2mg/L) with 0.2 mg/L of BAP gave greenish white hard callus. Callus induction was observed after 7 days of culturing of leaf samples (Table 1, 2; Plate 1).The highest response in node explant (84.3±2.6%) was observed on MS medium supplemented with 0.4 mg/L 2,4-D with 0.4mg/L kinetin which resulted in white soft callus; while, 87.6±2.53% 0.2 mg/L of NAA with 0.2mg/L BAP resulted in greenish white hard callus. Callus induction was observed after 6 days in case of node (Table 1, 2; Plate1). These results are in support of earlier investigations carried out for callus induction in *Ipomoea obscura* (L). using node as explant (A.Mungole et al., 2009). The highest response of callusing was observed in bud explant on MS medium supplemented with 0.2 mg/L of 2, 4-D plus 0.2 mg/L of kinetin which resulted in white callus (82.33±0.9). While, 0.8 mg/L of NAA with 0.8mg/l kinetin resulted in green callus (96.6±0.96%). Callus induction was reported in 6 days of culturing in medium with 2, 4-D plus Kinetin and 4 days in NAA plus Kinetin (Table 1, 2; Plate1). Growth of callus increased significantly and this covers the entire surface of the explant. In general, it was observed that NAA was the best source of auxin for callus induction along with kinetin(80– 100%) or with BAP (90-96%); then 2, 4- D with kinetin (40-90%) or with BAP (55-80%) (Table 1, 2).The callus produced by 2,4-D was white in contrast to dark green in NAA. MS

Table 1: Effect of different concentration of 2, 4- D with Kinetin and BAP on Callus induction

Auxins (mg/L)	Cytokines (mg/L)		% of callus response			Nature of Callus
2,4-D	Kinetin	BAP	Leaf explants	Node explants	Bud explants	
0.1	0.1	--	90±1.66	70±1.6	46.6±2.5	White, Soft
0.2	0.2	--	86.6±2.5	84.3±2.6	82.33±0.9	White, Soft
0.4	0.4	--	85±1.6	80.3±1.5	NR	White, Soft
0.8	0.8	--	94.3±2.54	75±1.05	NR	White, Soft
0.1	--	0.2	56.6±0.96	79.6±1.5	NR	White, Soft

Media – MS +3% sucrose, NR = No Response, Mean value of three readings.

Table 2: Effect of concentration of NAA with Kinetin and BAP on Callus induction

Auxins (mg/L)	Cytokines (mg/L)		% of callus response			Nature of Callus
2,4-D	Kinetin	BAP	Leaf explants	Node explants	Bud explants	
0.2	--	0.2	95.6±0.96	87.6±2.53	91.6±0.96	Greenish white, Hard
0.4	0.4	--	80±1.66	78.3±0.96	86.67±0.96	Greenish white, Hard
0.8	0.8	--	NR	93.3±0.96	96.6±0.96	Greenish white, Hard

Media: MS + 3%sucrose; NR= No response; Mean value of three readings.

Table 3: Effect of different concentration of Hormone(S) NAA(0.8 Mg/L) and Kinetin (0.8 Mg/L) on shoot regeneration and height attained from Node Explant of *Ipomoea obscura (L.)*

No .of. testtubes Inoculated	No. of.shoot per treatment	Shootlength in cm.	Shoot morphology
1	2	3.6	Thin Short
2	2	2.7	Thin Short
3	3	3.1	Thin Short
4	2	5.4	Green and long
5	4	3.8	Thin Short
6	2	7.5	Green and long
7	1	3.2	Thin Short
8	NR	NR	High callus induction
9	NR	NR	High callus induction
10	NR	NR	High callus induction

NR = No response

medium is frequently used for micropropogation of large number of plants.[5] It was reported that *T. bellerica* cultures grew better on MS medium in comparison to all other medium (Rathore et al.,2008). The medium for *in –vitro* multiplication of Drosera plants was MS medium. MS was reported superior medium for micropropogation of *Coptis teeta*.[6] Further studies were carried out for shoot regeneration capacity of the node. Shoot were initiated from the node explants by showing both direct and indirect organogenesis. The best result of shooting (7.5 cm; 4 shoots per treatment) was observed in MS medium supplemented with the combination of Kinetin (0.8 mg/l) and NAA (0.8 mg/l) after 17-19 days (Table 3; Plate1).

Conclusion

Depletion of wild population can be prevented through such invitro cultivation for further commercial exploitation. Amongst all the

Fig A: White Callus

Fig B: Greenish White Colour Callus

Fig C: Initiation of Shoot

Fig D: Multiple Shoots

explants tried for callus, the leaf was found to be the most suitable explant for callusing. NAA and BAP were found to be the most appropriate hormone concentration for callusing. Thus, the present investigation provides optimum parameters for callus and shoots induction. The multiple shooting of *Justica adathoda* (L).was also established for single nodal region on MS medium supplemented with NAA (0.8 mg/L) and Kinetin (0.8 mg/L). Thus this study provides a standard protocol to initiate multiple shoot culture,optimization of media content and hormonal concentration that may provide desired source of pharmacologically active plant constituents through callus culture.

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Original Article

Optimization of Doses of Talc Based *Fluorescent Pseudomonas* for the Management of Banded Leaf and Sheath Blight of Maize (*Zea Mays* L.)

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Abstract

Several strains of fluorescent pseudomonas were isolated from rhizosphere of different crops. Carrier-based formulations of two of these isolates were made using talc powder. Three doses of carrier-based formulations i.e.2 g, 4 g and 6 g of two isolates viz. ZRP-3 and ZRP-5 were tested as seed treatment, soil treatment and foliar sprays. Higher doses (4 g and 6 g) were found effective in reducing disease severity of banded leaf and sheath blight of maize (18.6%-40.0%) with all three methods of application. Higher doses also enhanced germination (10.5%-25.0%) of maize seeds when used as seed treatment and soil application.

Keywords

Fluorescent pseudomonads; *Rhizoctonia solani*; Carrier-based formulations.

Introduction

Banded leaf and sheath blight of maize (BL & SB) incited by *Rhizoctonia solanil* Kuhn; Exner is one of the major production constraints for maize in India as well as other maize growing countries. It was first reported from Sri Lanka as Sclerotial disease of maize [1]. Since then it has attained worldwide distribution. In India it was first time recorded from *Tarai* region of Uttar Pradesh [2]. The disease results in direct losses exhibiting premature death, stalk breakage and ear rot. Yield losses up to an extent of 97% have been reported.[3] Very few maize cultivars have shown resistance to this disease and chemical control measures provide only partial protection to the crop. Breeding for the resistance which has been very successfull tools for many crops is not able to keep pace with the development of more virulent races of the pathogens. This situation has dully prompted the pathologist to look for an alternative strategy for managing the disease. Bacterial flora has been used successfully for the control of plant disease and yield improvement.[4] Success of biological control largely depend upon the proper application of bio control agent for that proper dose of bio control agent for seed treatment, soil application and foliar spray. Therefore present investigation are carried out to optimize appropriate doses of formulated bio control agent for controlling banded leaf and sheath blight of maize.

Materials and Methods

Experiments were conducted in glass house using randomized complete block design with three replications. Earthen pots of 9 inches size filled with two kg of field soil thoroughly mixed

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with compost manure were used. The soil was then inoculated with free culture *Rhizoctonia solani* grown on sorghum grains. These pots were watered regularly and covered with polythene bags to maintained high relative humidity and kept for one week to allow the fungus for its establishment. Ten healthy seeds of maize cultivar Basilocal were seeds in each pot. Carrier based formulation of ZRP-3 and ZRP-5 was prepared on talk powder and used as per following methods.

Seed Treatment

Seeds of maize were treated with talk based formulation @ 2, 4 and 6 g/kg of seeds just before sowing.

Soil Treatment

Maize seeds were sown in pots containing field soil. After 20 DAS talk based formulations were manually placed in the root zone of plants in doses of 2,4 and 6 g/pot.

Foliar Spray

Talk based formulation was suspended in water separately @ 2,4 and 6 g/liter of water, allowed to settle for some time, filtered through muslin cloth and filtrates were sprayed at the appropriate time.

Data on germination percentage and disease severity were recorded following 1-5 rating scale as suggested by Ahuja and Payak, 1983[5] (where, 1= Healthy and 5= severely infected.

Result and Discussion

Effect of Different Doses of ZRP-3

All three doses of formulated bio control agent@ 2,4 and 6 g/kg of seeds increase the germination of maize plants (Table 1). However, maximum germination (905 and 88%) was recorded when the formulation was used in higher doses ie. 4, 6 g/kg of seeds. Similarly, soil application @ 6g/plote also enhance the germination, where as lower dose was ineffective. Non significant effect ware recorded in germination when the formulation was applied as foliar sprays. All three doses of the formulation reduced doses severity significantly when applied as seed treatment. Seed treatment @ 4g and 6g/K exhibited 30%

Table 1: Effect of different doses of ZRP-3 and ZRP-5 on germination and disease severity

Treatments	Germination (%)		Increase over control (%)		Disease (1-5)		Reduction over control (%)	
Seed Treatment	ZRP-3	ZRP-5	ZRP-3	ZRP-5	ZRP-3	ZRP-5	ZRP-3	ZRP-5
				Seed Treatment				
Control	76(60.6)	68(55.5)	-	-	5.0	5.0	-	-
2g/kg	84(66.4)	72(58.0)	10.5	5.8	4.0	4.0	20.0	20.0
4g/kg	90(71.5)	74(59.3)	15.4	8.6	3.5	3.5	30.0	30.0
6g/kg	88(69.7)	82(64.9)	15.7	20.5	3.5	3.3	30.0	33.4
CD (5%)	5.42	6.42	-	-	0.39	0.36	-	-
				Soil Application				
Control	70(56.7)	74(89.3	-	-	5.0	4.6	-	-
2g/plot	72(58.0)	80(63.4)	2.8	8.1	3.5	3.5	30.0	24.8
4g/plot	74(59.3)	82(64.9)	5.7	10.8	3.3	3.3	33.4	28.5
6g/plot	84(66.4)	88(69.7)	20.0	18.9	3.0	3.0	40.0	35.6
CD (5%)	6.29	8.03	-	-	0.46	0.38	-	-
				Foliar Application				
Control	76(60.6)	76(60.6)	-	-	4.6	5.0	-	-
2g/liter	76(60.6)	74(59.3)	0.0	-	4.3	4.3	7.1	13.4
4g/ liter	80(63.4)	76(60.6)	5.2	0.0	4.0	3.5	14.1	30.4
6g/ liter	74(59.3)	72(58.0)	-	-	3.5	3.3	24.8	33.4
CD (5%)	NS	NS	-	-	0.52	0.37	-	-

reduction in disease as compared to control. Higher doses of soil application showed even better disease reduction (40%). Similarly, foliar sprays of the formulation @ 6g/L resulted in 24.8% reduction in disease severity.

Effect of Different Doses of ZRP-5

The data indicates no significant effect of any dose on seed germination when formulation was used as seed treatment and foliar sprays (Table 1). However, higher doses (4 and 6g/plot) of soil applications enhanced germination (15.6% and 25%) significantly as compared to control, and lower doses (2g/plot). Significant reduction in disease severity was also recorded with higher doses (4g and 6g) of formulation when applied to seeds and in soil. Foliar sprays @ 6g/L also reduced the disease significantly. In general, lower dose (2g) was ineffective in reducing disease severity. Several workers have been able to control foliar diseases using *fluorescent pseudomonas* formulations.[6] Similar results have been reported by Shiv Kumar *et al* [7] who tested the different doses of peat based formulation of *fluorescent pseudomonas* against banded leaf and sheath blight of maize and observed that higher doses of seed treatment, soil application and foliar sprays effectively reduced disease severity as compared to lower doses as reported earlier.[8]

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Original Article

Determination of Replacement Value of Chemical Fertilizers with Organics in Rice Crop

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Abstract

A field experiment was carried out during kharif season of 2002 and 2003 to assess the extent of reductions in yield due to application of inorganic fertilizers below the recommended level. The NPK levels applied were @ 100%, 75% and 50% of recommended fertilizers through inorganic fertilizers. The higher values of NPK elements are required for identical increase in yield if the sources are organics. Among organics, higher amounts for Bagasse NPK are required for same increase in the yield. The NPK was twice as effective as FYM, NPK and about 4 times as effective as Bagasse NPK in terms of increasing the yield of rice. The fertilizer P was about 4 times as efficient in increasing P uptake by rice as FYM P and more than 10 times higher as compared to Bagasse P. The fertilizer K was about 6 times and 10 times more effective than FYM and Bagasse K, respectively in enhancing the K uptake by rice.

Keywords

Replacement value of inorganic; Organic; Rice.

Introduction

Continuous use of high levels of chemical fertilizers had led to soil degradation resulting in reduced crop productivity. Nambiar and Abrol[1] reported a declining trend in the productivity of rice even when grown under adequate application of N, P and K. Depletion of organic carbon, lower moisture retention and reduction in water stable aggregates were reported to be the prime reason for unsustainability of rice production in rice-wheat system.[2] Hence, positive impact of organic manures/residue additions in such fields is expected. Incorporation of crop residue preserves plant nutrients as well as improves the physico-chemical and biological properties of soil improving the ecological balance of rhizosphere. The long-term sustainable production needs balanced supply of essential plant nutrients in available form along with suitable physical, chemical and biological properties of soil to attain a better growth and development of crop and efficient utilization of nutrients from the rhizosphere. The balanced nutrition involves systematic exploitation and replenishment of potential of soil resources, chemical fertilizers, bio-fertilizers and organic manures.

Materials and Methods

The experiment was conducted at the Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil of experimental site was loam in texture (0-15 cm) high in Organic carbon (9.0 g kg^{-1}) and available N, P

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and K were 210 kg, 22.6 kg and 240.7 kg ha^{-1} while S, Zn and B were 10 mg kg^{-1} , 0.45 mg kg^{-1} and 0.66 mg kg^{-1} soil, respectively. The soil was neutral in reaction (pH 7.46) with 0.2l dSm^{-1} EC. During kharif season in both the years, rice variety *Govind* was taken with recommended practices. The experiment with eighteen treatment combinations, replicated thrice was planted in R.B.D. in 20 x 10 cm spacing. The full dose of P and K along with 1/3 of N as per treatment was applied at the time of planting and remaining N was top dressed in two equal doses. The grain and stover samples were analyzed for N, P& K contents with standard chemical procedures during both the years. The uptake was calculated from the yield data in conjunction with their respective contents. The apparent nutrient recovery (REN) and Agronomic efficiency of applied nutrient (AEN) were calculated by using following formulae:

$$\text{REN} \quad (\%) = \frac{\text{A - B}}{\text{C}} \times 100$$

$$\text{AEN (kg grain kg}^{-1}\text{ nutrient)} = \frac{\text{D - E}}{\text{C}}$$

Where,

A = Nutrient uptake in treated plot (kg ha^{-1})

B = Nutrient uptake in corresponding control plot (kg ha^{-1})

C = Amount of nutrient applied through a particular source (kg ha^{-1})

D = Grain yield in treated plot (kg ha^{-1})

E = Grain yield in corresponding control plot (kg ha^{-1})

Results and Discussion

Agronomic Efficiency of Nutriments

In terms of the increase in yield of rice with unit increase in the fertilizer NPK or FYM and Bagasse NPK, (Table 1) it was found that for one kg increase in yield (fertilizer NPK/yield increased) 0.12 and 0.13 kg of fertilizer NPK was required during 2002 and 2003, respectively. For the similar yield (FYM NPK/yield increased) increase, the FYM NPK required had an average values (5 and 10 t ha^{-1} FYM) of 0.22 and 0.52 and the Bagasse NPK (Bagasse NPK/yield increased) required was (average values of 5 and 10 t ha^{-1} Bagasse) 0.89 and 1.72 kg during 2002 and 2003, respectively. This clearly shows that higher values of NPK elements are required for identical increase in yield if the sources are organics. Among organics, higher amounts for Bagasse NPK are required for same increase in the yield. In terms of increase in yield for fertilizer NPK required (yield increased/ fertilizer NPK) the average values were 9.45 and 10.58 kg during the year 2002 and 2003, respectively (Table 2). Similar average values (5 and 10 t ha^{-1}) of FYM NPK (yield increased/FYM NPK) were 4.82 and 2.78 kg and the average (5 and 10 t ha^{-1} Bagasse) values for Bagasse NPK were 1.59 and 2.17 kg, respectively. It seems, therefore, that fertilizer NPK was twice as effective as FYM NPK and about 4 times as effective as Bagasse NPK in terms of increasing the yield of rice.

In terms of increase in N uptake of rice, kg^{-1} of fertilizer N applied, the average values for the year 2002 and 2003 were (increase in N uptake/

Table 1: Agronomic efficiency of added NPK nutrients in Rice, Kg^{-1} of yield increase (Applied NPK/Yield Increase)

Nutrients and sources	2002				2003			
	RF	75% of RF	50% of RF	Mean	RF	75% of RF	50% of RF	Mean
Fertilizer NPK	0.08		0.15	0.12	0.19		0.06	0.13
FYM (@ 5 t ha^{-1}) NPK	0.22	0.23	0.17	0.21	1.29	0.60	0.22	0.70
FYM (@ 10 t ha^{-1}) NPK	0.25	0.20	0.20	0.22	0.35	0.39	0.24	0.33
Bagasse (@ 5 t ha^{-1}) NPK	1.83	0.36	0.37	0.85	6.58	0.33	0.15	2.35
Bagasse (@ 10 t ha^{-1}) NPK	1.24	0.88	0.64	0.92	1.58	0.75	0.91	1.08

Average of FYM (@5 and 10 t ha^{-1}), NPK = 0.22 (2002) and 0.52 (2003)
Average of Bagasse (@5 and 10 t ha^{-1}), NPK = 0.89 (2002) and 1.72 (2003)

fertilizer N) 0.39 and 0.44 kg, respectively (Table 3). Corresponding values for each kg increase in N uptake (increase in N uptake/FYM N) were 0.39 and 0.32 kg for (5 and 10 t ha^{-1}) FYM N and (increase in N uptake/Bagasse N) 0.20 and 0.27 kg for Bagasse N during 2002 and 2003, respectively.

In terms of increase in P uptake by rice, kg ha^{-1} of fertilizer P added the average values for the year 2002 and 2003 (increase in P uptake/ fertilizer P) were 0.36 and 0.48 kg, respectively. Corresponding values for each kg increase in P uptake (increase in P uptake/FYM P) averaged at (5 and 10 t ha^{-1} FYM) 0.08 and 0.07 kg FYM P and (increase in P uptake/Bagasse P) 0.03 and 0.03 Bagasse P during 2002 and 2003,

Table 2: Agronomic efficiency of added NPK nutrients in Rice, Kg^{-1} of Nutrient Applied (Yield Increased/Applied NPK)

Nutrients and sources	2002				2003			
	RF	75% of RF	50% of RF	Mean	RF	75% of RF	50% of RF	Mean
Fertilizer NPK	12.05		6.84	9.45	5.26		15.91	10.58
FYM (@ 5 t ha^{-1}) NPK	4.64	4.28	6.04	4.99	0.77	1.66	4.61	2.35
FYM (@ 10 t ha^{-1}) NPK	3.99	5.01	4.96	4.65	2.83	2.55	4.24	3.21
Bagasse (@ 5 t ha^{-1}) NPK	0.55	2.81	2.68	2.01	0.15	3.04	6.76	3.32
Bagasse (@ 10 t ha^{-1}) NPK	0.81	1.14	1.57	1.17	0.63	1.34	1.10	1.02

Average of FYM (@5 and 10 t ha^{-1}), NPK = 4.82 (2002) and 2.78 (2003)
Average of Bagasse (@5 and 10 t ha^{-1}) , NPK = 1.59 (2002) and 2.17 (2003)

Table 3: Uptake of Nutrients per Kg of nutrient applied in Rice (Nutrient Uptake increased/Applied Nutrient)

Nutrients and sources	2002				2003			
	RF	75% of RF	50% of RF	Mean	RF	75% of RF	50% of RF	Mean
Fertilizer								
N	0.55	0.22		0.39	0.32	0.56		0.44
P	0.34	0.37		0.36	0.39	0.57		0.48
K	1.85	1.13		1.49	0.87	2.79		1.83
FYM (@ 5 t ha^{-1})								
N	0.41	0.40	0.23	0.35	0.14	0.24	0.20	0.19
P	0.09	0.07	0.07	0.08	0.03	0.05	0.06	0.05
K	0.30	0.15	0.22	0.22	0.13	0.14	0.13	0.13
FYM (@10 t ha^{-1})								
N	0.60	0.46	0.22	0.43	0.55	0.44	0.32	0.44
P	0.09	0.09	0.07	0.08	0.08	0.08	0.08	0.08
K	0.35	0.30	0.30	0.32	0.27	0.15	0.29	0.24
Bagasse (@5 t ha^{-1})								
N	0.50	0.48	-0.43	0.18	0.04	0.27	0.64	0.32
P	0.02	0.05	0.03	0.03	-0.004	0.05	0.08	0.04
K	0.26	0.15	0.23	0.21	0.12	0.14	0.33	0.20
Bagasse (@10 t ha^{-1})								
N	0.30	0.31	0.06	0.22	0.26	0.17	0.19	0.21
P	0.03	0.03	0.02	0.03	0.02	0.02	-0.001	0.01
K	0.07	0.06	0.09	0.07	0.20	0.07	-0.09	0.06

Average of FYM (@ 5 and 10 t ha^{-1})				Average of Bagasse (@5 and 10 t ha^{-1})			
N	=	0.39 (2002)	0.32 (2003)	N	=	0.20 (2002)	0.27 (2003)
P	=	0.08 (2002)	0.07 (2003)	P	=	0.03 (2002)	0.03 (2003)
K	=	0.27 (2002)	0.19 (2003)	K	=	0.14 (2002)	0.13 (2003)

Table 4: Recovery efficiency (%) of added nutrients in Rice crop

Nutrients and sources	2002				2003			
	RF	75% of RF	50% of RF	Mean	RF	75% of RF	50% of RF	Mean
Fertilizer								
N	55.00		22.10	38.55	32.33		56.07	41.15
P	33.74		37.25	35.50	38.63		57.25	47.94
K	184.99		113.33	149.16	87.27		278.51	182.89
			FYM (@ 5 t ha^{-1})					
N	40.75	39.73	23.10	34.53	14.04	23.58	20.15	19.26
P	9.25	6.63	7.38	7.75	2.97	4.80	5.77	4.51
K	30.33	14.91	22.07	22.44	13.23	13.82	13.33	13.46
			FYM (@10 t ha^{-1})					
N	59.55	46.27	22.37	42.73	54.55	43.60	31.55	43.23
P	9.25	8.81	6.94	8.33	8.23	8.06	8.09	8.13
K	35.07	30.40	29.82	31.76	27.11	14.82	28.95	23.63
Bagasse (@5 t ha^{-1})								
N	50.16	48.40	-41.20	19.12	3.50	27.42	64.42	31.78
P	2.40	4.90	3.40	3.57	-0.36	4.55	8.36	4.18
K	25.69	15.19	22.69	21.19	11.64	14.12	33.21	19.66
Bagasse (@10 t ha^{-1})								
N	29.24	29.92	5.84	21.67	26.38	16.88	18.67	20.64
P	2.65	2.60	2.35	2.53	2.32	2.27	-0.14	1.48
K	7.03	6.25	8.88	7.39	19.91	7.27	-9.45	5.91

Average of FYM (@ 5 and 10 t ha-1)				Average of Bagasse (@ 5 and 10 t ha-1)			
N	=	38.63 (2002)	31.25 (2003)	N	=	20.40 (2002)	26.21 (2003)
P	=	8.04 (2002)	6.32 (2003)	P	=	3.05 (2002)	2.83(2003)
K	=	27.10 (2002)	18.55 (2003)	K	=	14.29 (2002)	12.79 (2003)

respectively.

Thus fertilizer P was about 4 times as efficient in increasing P uptake by rice as FYM P and more than 10 times higher as compared to Bagasse P.

In terms of increase in K uptake by rice, kg ha^{-1} of fertilizer K applied, the average values for the year 2002 and 2003 (increase in K uptake/fertilizer K) were 1.49 and 1.83 kg, respectively. Corresponding values for each kg increase in K uptake (increase in K uptake/FYM K) (5 and 10 t FYM) for FYM K were 0.27 and 0.19 kg and (increase in K uptake/Bagasse K) for Bagasse K were 0.14 and 0.13 kg during 2002 and 2003, respectively. Thus the fertilizer K was about 6 times and 10 times more effective than FYM and Bagasse K, respectively in enhancing the K uptake by rice.

Apparent Recovery Efficiency of Nutrients

The apparent recovery percentage of applied nutrients from various organic and inorganic sources in rice crop were worked out from the uptake values of concerned nutrients and the doses applied from different sources (Table 4). It was observed that the applied nutrients in crop showed an average apparent recovery of 38.55 and 41.15 per cent for N, 35.50 and 47.94 per cent for P and 149.16 and 182.89 per cent for K during 2002 and 2003, respectively. Similarly, the corresponding average values of organic sources (average of 5 and 10 t ha^{-1}) like FYM N were 38.63 and 31.25 per cent, FYM P 8.04 and 6.32 per cent and FYM K 27.10 and 18.55 per cent of added nutrients during 2002 and 2003, respectively. Likewise, Bagasse gave the values of 20.40 and 26.21 per cent for N, and 3.05 and 2.83 per cent for P and 14.29 and 12.79 per cent for K during the experimentation in the years 2002 and 2003, respectively.

Increasing cost of fertilizers enhancing incidence of multiple nutrient deficiency and deterioration of physical properties of soil are known to be responsible for lower yields in the areas having fertility of soils. It has been found

that application of most of the nutrients through green manure or with other organic manure like FYM, Compost, Blue green algae and Bagasse etc enhancing the soil fertility .The productivity of system could be sustain through the application of organic sources of nutrients. Hedge and Dwivedi [3] explored possibilities to substitute 50 per cent N need of rice through FYM without any significant reduction in the productivity of rice-wheat system at Palampur, R.S. Pura and Kalyani. FYM has been found better than Bagasse as it produced more NPK contents as compared to Bagasse. It is could be due to high C:N ratio of Bagasse and also reported elsewhere.[4,5,6] As evident from the present study that high quantities of organics are required to achieve the adequate levels of NPK, integration of organics with chemical fertilizers seems to be the right approach not only in maintaining high productivity but also in providing maximum stability in crop production.[2,7]

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[9] National Statistics Online—Trends in suicide by method in England and Wales, 1979-2001. www.statistics.gov.uk/downloads/theme_health/HSQ 20.pdf (accessed Jan 24, 2005): 7-18. Only verified references against the original documents should be cited. Authors are responsible for the accuracy and completeness of their references and for correct text citation. The number of reference should be kept limited to 20 in case of major communications and 10 for short communications.

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