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Inoculation Approach to Legume Crops and Their Production Assessment in Pakistan - A Review

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Abstract: In Pakistan the legumes are grown mostly in rain-fed areas of marginal lands where soil fertility and native rhizobial populations are low. The result is lower yield of legumes compared with other countries. The experiments carried out by the scientists of National Agricultural Research Centre (NARC), Islamabad and other research institutes, have shown significant yield increases of legumes by inoculation with appropriate rhizobium strains. In these experiments the highest yield increase was noted in case of soybean ranging 30-196 percent. Yield increase of chickpea and peas was generally in the range of 20-40 percent, whereas increase in case of other food legumes i.e., lentil, mung and mash was 10-20 percent. Although these yield increases are quite reasonable, the adoption of inoculant is almost negligible, not increasing beyond 20,000 ha per annum. The demand from farmers has not increased. The farmers and field workers are needed to be educated with the technology in order to enhance use of inoculants. The inoculant production in the country is far below than required but it could be easily increased many fold provided its demand is created. Also, field worker/farmers are not properly educated in their use. There is a strong need for the private sector to develop large-scale production facilities and supply of proper rhizobial inoculants for the various legumes grown in Pakistan.

Key word: Production assessment, Pakistan, Legume crops

Introduction

Legumes are grown on 1.6 million hectares, that is 1.9 percent of total cultivated land of Pakistan. Almost all of this is in two northern provinces, Punjab and the North Western Frontier province (NWFP) and is concentrated in Thal and Potohar divisions (Punjab) and in the Malakand (NWFP). Lathyrus and chickpea are also grown as irrigated crops in the Sindh province (Aslam *et al*., 1994, 1995). The yield of legumes in Pakistan is 0.5 0.6 t ha^{-1} (except groundnut = 1.1 t ha^{-1}) which is lower than most other countries of the world. Some times country has to spend a lot of money to import pulses (especially chickpea) to meet national food requirement. Therefore, their is a strong need to increase yield of legumes in Pakistan.

Approximately one percent of these legume crops are inoculated, even though Pakistani soils have either nil or low populations of effective rhizobia and low N-supplying capacity because of low organic matter (0.3-1.0%) levels (Khan *et al.,* 1989; Ladha *et al*., 1996; Aslam *et al*., 1997). Farmers have not been educated to the benefits of inoculation and have little concept of the practice, particularly those who are less educated and less progressive. On the other hand, the better educated legume farmers use inoculant on 8,200 hectares (ha) annually. This inoculant is produced by the government agricultural research institutions such as National Agricultural Research Centre (NARC), Islamabad, Ayub Agricultural Research Institute (AARI), Faisalabad, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Nuclear Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad and Agricultural Universities, e.g., University of Agriculture, Faisalabad.

Materials and Methods

Scientists at NARC have conducted various field and green house experiments since mid 1980s to establish the positive effects of inoculation on commonly grown legumes and to evaluate different strains of rhizobia. The legume species include chickpea, soybean, lentil, mung/mash beans, groundnut and peas. The inoculant for all these experiments was prepared at NARC, using Rhizobial strains acquired from international sources as well as isolated form local soils. Inoculant was applied by seed coating method just before sowing. In these experiments no mineral nitrogen as supplied, except in a faw cases where N was applied as basal/starter dose. Phosphorus was applied through mineral fertilizer in most of these cases.

Results and Discussion

Crop Species

Chickpea: Chickpea is the major legume grown in Pakistan. However, almost all of it is grown in marginal land in rain-fed areas. The soils of these areas have very low fertility. The climate of these areas is very harsh which often results in a low rhizobial population. The result is lower yield of the crop compared with other countries (Rupela and Saxena, 1987; Beck, 1992; Doughton *et al*., 1995; Herridge *et al*., 1995; Aslam *et al*., 1997; Mahmood and Aslam, 1999). Inoculation experiments carried out in various areas of the country often have shown significant increases in chickpea yield (Table 1 and 2). The results in Table 1 show 100 percent increase in nodulation by applying inoculant, whereas increase in yield ranged from 20-33 percent. The nitrogen fixation was also significantly increased with inoculation. In demonstration cum field experiments carried out at 20 sites in Thal during 1995-96, the average yield increase was 43 percent (Table 2). Some local isolates from chickpea fields have been reforming excellently in the harsh climate of Thal.

Soybean: Soybean is a newly introduced crop in Pakistan. Populations of *Rhizobium japonicum* is virtually absent in local soils. In several experiments no nodulation was observed in plants grown without inoculation (Table 3). Therefore, no local isolated Rhizobium could be acquired and all the strains used for inoculation were imported from NifTAL, Hawaii which have performed well in Pakistan. In experiments carried out throughout the country a 40-50 percent increase in yield due to inoculation has been very common. Occasionally, yield responses in the range of 100-200 percent have been noted (Table 3).

The experiments were carried out in various areas of the country during several years. Similar results have been obtained from more than a dozen other inoculation experiments on soybean. In an experiment carried out at NARC, soybean yield obtained with inoculation was comparable with that obtained from application of 100 kg fertilizer N (Table 4). The results of these experiments on soybean have been given in Table 3. The yield increases with inoculation at Site 1 and 3 are almost similar. The increases in yield over control range from 25 48 percent. Response of inoculation at site 2 was excellent that ranged 123 196 percent. In another experiment, carried out at NARC, inoculation was compared with mineral nitrogen. The effect of Rhizobium inoculation was comparable to 100 kg N ha^{-1} (Table 4) which is equivalent to 4.2 bags of urea.

Table 1: Effect of Rhizobium strains on different parameters of Chickpea during growth season 1994-95. (Average of four repeats)

Rhizobium Strains	Nodule Mass	N fix (%)	Yield (t ha^{-1})	% increase over control
Uninoculated	143.67	41.0	1.64	--
TAL-1148	280.67	51.5	1.93	20.00
Thal-8	248.00	47.2	1.85	17.50
Mixture	337.67	71.8	2.07	28.50

Mixture = TAL-1148 + Thal-8

Table 2: Yield of Chickpea in Rhizobial Inoculation dejnontration plotsdurinq1995-96

Farmer	Site	Yield (kg ha^{-1})		
		Inotulated	Uninoculated	% increase over control
Tehsil Kalurkot				
Allah Bakhsh	Dagar Awan	988	593	67
Ghulam Muhammad	Zammewala	939	741	27
Said Rasool	Jandwala	534	511	4
Sultan Khan	Alikhei	1065	1020	4
Allah Bakhsh Joia	Joia	539	484	11
Muhammad Ramzan	Dale	914	642	42
Muhammad Hayat	Dala	766	677	13
Dost Muhammad	Shah Alam	711	506	40
Karam Hussain Zafar	Shah Alam	1482	865	71
Abdur Rehman	Dagar Awan	865	605	43
Amir Hasan Khan	Hasanwala	235	988	25
Nasir A. Khan	Hasanwala	963	642	50
Ahsan Khan	Hasanwala	988	519	90
Haji Abbas Dodi	Dodi Khel	1729	1235	40
Waqar Khan Dodi	Dodi Khel	1482	1235	20
Mushtaq Khan Dodi	Dodi Khel	1235	988	25
Tehsil Bhakkar				
Kamar Din	Chak 55/TDA	766	506	51
Ghulam Nabi	Chak 55/TDA	1297	556	133
Tehsil Mankera				
Muhammad Aslam	Saniasi Adda	1398	741	89
Faiz Muhammad	Saniasi Adda	865	494	75
Average of 20 Inoculated Fields		1038	727	43

It was unreplicated. Plot size was 0.5- 1.0 ha; half of it was inoculated and other was uninoculated. Phosphorus was applied to all plots at 60 kg P_2O_5 ha^{-1}

Table 3: Effect of Rhizobial inoculation on Soybean noduiation and yield on farmer's fields, 1988-90

	Nodulation (plant^{-1})			Yield (t ha^{-1})			Yield increase/control (%)		
Rhizobium strains	Site[1]	Site[2]	Site[3]	Site[1]	Site[2]	Site[3]	Site[1]	Site[2]	Site[3]
Uninoculated	0	2	0	1.6	1.6	1.3	--	--	--
TAL-397	4	48	14	2.2	3.8	1.9	35	142	48
TAL-102	4	41	7	2.3	3.5	1.6	40	123	26
TAL-377	4	42	9	2.2	4.6	1.7	35	196	31
Mixture of all	4	52	6	2.4	3.9	1.6	45	150	25

Site[1] = Rice area in Punjab during 1988. Site[2] = Rice area (other site) in Punjab during 1989. Site[3] = NARC during 1990

Table 4: Effect of Rhizobium inoculation on soybean yield at NARC, Islamabad, spring 1991

Treatments	Nodulation (plant^{-1})	Pods (plant^{-1})	Grain yield (t ha^{-1})	% increase over control
Uninoculated	7	36	1.5	--
Inoculated	40	58	2.5	68
20 kg N ha^{-1}	18	44	2.0	34
50 kg N ha^{-1}	16	48	2.2	43
75 kg N ha^{-1}	10	47	2.4	56
100 kg N ha^{-1}	19	62	2.5	67
125 kg N ha^{-1}	22	64	2.6	75
150 kg N ha^{-1}	20	75	2.6	75
SD (5%)	13.67	11.4	185	

Table 5: Area, grain yields and inoculant produced for the major grain legumes grown in Pakistan

Legum crops	Total Area (m. ha)	Total production (m. ha.)	Average yield (t ha^{-1})	Inoculant production for area (ha)
Chickpea	1.12	0.68	0.61	10,000
Lentil	0.07	0.04	0.52	3,000
Mungbean	0.20	0.09	0.46	3,000
Mashbean	0.06	0.03	0.49	2,000
Peas	0.14	0.08	0.55	500
Groundnut	0.10	0.11	1.10	2,000
Other Pulses	0.01	0.01	0.50	500
Total	1.70	1.04		21,000

Source = GOP (1996) and FAO (1984)

Other Legumes: Generally all legumes are grown on marginal lands of harsh climate and average yield is very low (Table 5). Experiments conducted by NARC scientists on other commonly grown legumes (groundnut, peas, lentil, mash bean and mung bean) have shown significant increases in yield due to inoculation. Effects on groundnut and peas are similar to chickpea. However, yield response in lentil, mung and mash due to inoculation is less ranging 10, 20 percent. The cultures used for inoculation are either acquired from international centres or isolated from local soils.

In addition to food legumes inoculation experiments have also been carried out on forage legumes, i.e., sesbania, guar, berseem and lucern. The response of inoculation on these crops is also significantly positive.

Future Production and Use of Legume Inoculants in Pakistan: All legume inoculant research and development in Pakistan has traditionally been conducted by the government-funded institutes like NARC, NIBGE, AARI and the Agricultural Universities such as NWFP, Agricultural University, Peshawer. This is now changing. For the last three years the Engro-Chemical Pakistan Limited (ECPL: a one of the largest fertilizer companies in Pakistan) is collaborating with NARC. According to an agreement signed between NARC and ECPL, since 1996, the company (ECPL) is handling the distribution of inoculants produced by NARC. Over the last three years farmers awareness to the use of chickpea inoculant has increased significantly. The surveys conducted after harvest have shown that above 80 percent farmers were very happy with the performance of Rhizobium inoculant. The use of inoculants has also increased. It is anticipated that the number of packets for chickpea sold to farmers will increase from the current 15,000/annum to 50,000/annum by the year 2000.

Most of the legumes are grown in rain-fed areas of marginal lands where Indigenous Rhizobial population is low in these soils. The result is low yield of legumes as compared with other countries. Other than low moisture (for which nothing can be done in these low rainfall areas) low soil fertility and low Rhizobial population is the main cause of low legume yield in these areas. The experiments carried out by scientists of NARC and other research institutes have shown significant yield increase of legumes by inoculation with appropriate Rhizobium strains. However, use of inoculants is very low: just above 1.3 percent of the total area under legumes which is negligible. Farmers awareness about inoculant use is almost nil. There is a strong need to properly educate the field/extension workers and farmers inoculant technology, its usage and benefits to the crops. Over the last few years some efforts have been done in chickpea growing areas of Thal but there is insufficient. The present inoculant production facilities are also far below than requirement, although there are enough for current demand.

Although the inoculant production centres are sufficiently meeting the current demand, the overall production facilities in the country are far below that the total requirement. There is a strong need for the private sector to develop large-scale production and supply of proper Rhizobial inoculants for various legumes grown in Pakistan.

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