



Effect of chemical fertilizers and biofertilizers on rajmash (*Phaseolus vulgaris*) in cold desert region of North-western Himalayas

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Received: 27 October 2015; Accepted: 24 April 2018

ABSTRACT

A field experiment was conducted to study the combined effect of chemical fertilizers and biofertilizers on growth, yield and economics of rajmash (*Phaseolus vulgaris* L.) at Highland Agricultural Research and Extension Centre, Kukumseri during two consecutive summer seasons of 2012 and 2013. The experiment was laid out in randomized block design with nine treatments and replicated thrice. Growth, yield attributes and yield were significantly increased with combined application of chemical fertilizers and biofertilizers. The tallest plants were recorded in T₆ (N₆₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and phosphate solubilizing bacteria) while the shortest plants were in T₉ (N₀P₀K₀BF₀). Significantly higher values of pod length, seeds per pod, seed index, seed yield and straw yield were also recorded in T₆. Maximum mean value of dry matter efficiency and harvest index was observed in T₇ (N₆₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB) while maximum mean value of unit area efficiency, net returns and B:C ratio was in T₆. Based on the mean value of two years, T₆ resulted in 81.11, 77.48, 77.49, 172.05 and 65.32% higher dry matter production, unit area efficiency, seed yield, net returns and B:C ratio, respectively as compared to control treatment (T₉). Maximum mean profitability (₹1477/ha/day) was also recorded in T₆. Integrated application of 60 kg N, 60 kg P₂O₅ and 30 kg K₂O/ha along with seed inoculation with *Rhizobium* and PSB proved to be the best treatment for higher productivity and profitability of rajmash crop in cold desert region of North-western Himalayas.

Key words: Fertilizers, Productivity, Profitability, Phosphate solubilizing bacteria, *Rhizobium* bacteria

In India, the cold desert region of North-western Himalayas constitutes 79,278 sq km of area spread over Ladakh region of Jammu and Kashmir, Lahaul and Spiti, Kinnaur and Pangi areas of Chamba district of Himachal Pradesh. The region is a vast stretch of harsh, inaccessible and arid temperate area. The economic growth of the inhabitants is hindered by a variety of biotic, abiotic and eco-physiological factors showing distinct signs of unsustainability (Sharma and Chauhan 2008). In Himachal Pradesh, the cold desert area constitutes about 42% of its total geographical area. The climate is extremely cold and heavy snowfall occurs during winter. The temperature at some places remains several degrees below zero level. There is a single cropping season starting from April to end of September or early October when the mean minimum and maximum temperatures range between 12°C to 24°C. Occasionally it may range from as low as 5°C to 30°C.

The population of the region is entirely rural (100%) with 77.24% literacy rate (Anonymous 2011) and economically backward. The potential cash crops grown in the area include peas, potato and rajmash.

Rajmash (*Phaseolus vulgaris* L.) is known by different names in the world. In the form of vegetable, it is named as french bean, common bean, snap bean and green bean whereas in the form of pulse, it is known as haricot bean, dry bean, rajmash and navy bean (Singh *et al.* 2014). Rajmash is a short duration non-traditional grain legume and is inefficient in symbiotic nitrogen fixation as it lacks nodulation due to the absence of a nodulation gene regulator. As nodulation is poor in rajmash, it requires more nitrogen and phosphorus for root development. It is the only pulse crop grown in the cold desert area of Himachal Pradesh. It is a very nutritive crop containing 20.69 to 25.81% crude protein, 1.72% fats and 72.42% carbohydrates (Sood *et al.* 2003). It is also rich in dietary fibre, potassium, selenium, molybdenum, thiamine, vitamin B₆ and folic acid (Turuko and Mohammed 2014). Rajmash is a main source of protein for vegetarian population in the region. It is also a major source of income for the tribal farmers as there is a great demand of the rajmash in the plains of the country due to its better quality and taste. In the cold desert region, there is scarcity of organic manures. Tribal farmers are not

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economically sound to apply adequate nutrients through chemical fertilizers to their crops owing to their increasing prices. Improper quantity of nutrient supply in crop causes malnutrition or under-nourishing that reduces the production of crop, even if all the practices are adopted in appropriate manner (Rajput *et al.* 2006). Soil micro-organisms play a significant role in regulating dynamics of organic matter decomposition and the availability of plant nutrients. Bio fertilizers/microbial inoculants, an important component of integrated nutrient management lead to productive and sustainable agriculture. Microbial inoculants, a low-cost input increase crop profitability (Chen 2006). Integrated nutrient management may lead to reduction in the dose of chemical fertilizers to a level that is within the reach of small and marginal farmers. Considering the above said facts, the present investigation was undertaken to study the combined effect of chemical fertilizers and bio fertilizers on growth, yield and economics of rajmash crop.

MATERIALS AND METHODS

A field experiment was conducted during two consecutive summer seasons of 2012 and 2013 at the Research Farm, Highland Agricultural Research and Extension Centre of CSK Himachal Pradesh Agriculture University, Kukumseri (32° 44' 55" N latitude and 76° 41' 23" E longitude, and 2672 m above the mean sea level), Lahaul & Spiti, Himachal Pradesh, India. The soil of the experimental site was sandy loam in texture and acidic in reaction (6.1) with 10.8 g organic carbon/kg soil, 247 kg available N/ha, 28 kg available P/ha and 289 kg available K/ha. Average annual rainfall of the region is 250 mm, but it ranges from very low at 90 mm to as high as 1200 mm and most of it is received as snowfall in winter.

The experiment was laid out in randomized block design (RBD) with nine treatment combinations (T₁: N₂₀P₆₀K₃₀; T₂: N₂₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB, T₃: N₄₀P₆₀K₃₀; T₄: N₄₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB, T₅: N₆₀P₆₀K₃₀; T₆: N₆₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB, T₇: N₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB, T₈: N₀P₆₀K₃₀ + soil inoculated with *Rhizobium* and PSB and T₉: N₀P₀K₀BF₀). Treatments were allocated randomly in the different experimental plots using random table. Each treatment was replicated thrice.

Kanchan (HPR 35) variety of rajmash having short and bushy stature, early maturity and bold seeded with light pink colour was used as test crop. N, P and K were supplied through chemical fertilizer namely urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. *Rhizobium* and phosphate solubilizing bacteria (PSB) were used as biofertilizers. The crop was sown at 30 cm row spacing during the first week of June 2012 and 2013. Seed rate was kept @100 kg/ha. Seeds were treated with fungicide (Bavistin) @ 2.5 g/kg seed. Pendimethalin (Stomp 30 EC) was sprayed @ 4.5 l/750 l of water/ha within 48 hr of sowing for the control of weeds. Other recommended package of practices was also followed in the production of rajmash crop. Plant height, dry matter production, yield

attributes, yield, harvest index, dry matter efficiency, unit area efficiency, net returns and B:C ratio were recorded and computed after the harvest of the crop. Dry matter efficiency (DME) and unit area efficiency (UAE) were calculated by using the following formula:

$$\text{DME (percent/day)} = \frac{\text{Grain yield}}{\text{Total dry matter production}} \times \frac{100}{\text{Duration of crop}}$$

$$\text{UAE (kg/ha/day)} = \frac{\text{Grain yield}}{\text{Land area}} \times \frac{1}{\text{Duration of crop}}$$

Statistical differences between different treatment combinations of chemical fertilizer and biofertilizer and their effect on growth and yield were tested with Fisher's least significant difference (P=0.05) test (Fisher and Yates 1949) using analysis of variance (ANOVA) for randomized block design as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The growth, yield attributes and yield were significantly influenced by integrated application of chemical fertilizers and biofertilizers.

Growth

Application of chemical fertilizers in combination with biofertilizers significantly increased the height of rajmash plants (Table 1). The tallest plants were recorded in T₆ (N₆₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB) while the shortest plants were in T₉ (N₀P₀K₀BF₀). In 2012, plant height increased with 20 kg N plus 60 kg P₂O₅ and 30 kg K₂O/ha along with biofertilizers only. In the same year, similar plant height was observed in T₇, T₈ and T₉.

Table 1 Plant height and dry matter production as influenced by combined application of chemical fertilizer and biofertilizer

Treatment	Plant height (cm)		Dry matter production (q/ha)	
	2012	2013	2012	2013
T ₁	36.50	36.16	46.07	52.50
T ₂	36.89	36.23	46.89	51.00
T ₃	41.80	37.20	52.49	54.12
T ₄	42.05	37.56	52.73	51.00
T ₅	42.77	38.46	48.41	54.37
T ₆	43.05	38.83	48.20	66.87
T ₇	31.29	34.16	44.91	35.62
T ₈	31.52	34.73	44.32	39.37
T ₉	29.66	30.90	28.44	35.10
CD (P=0.05)	3.38	3.43	8.50	9.42

T₁: N₂₀P₆₀K₃₀; T₂: N₂₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB; T₃: N₄₀P₆₀K₃₀; T₄: N₄₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB; T₅: N₆₀P₆₀K₃₀; T₆: N₆₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB; T₇: N₀P₆₀K₃₀ + seed inoculated with *Rhizobium* and PSB; T₈: N₀P₆₀K₃₀ + soil inoculated with *Rhizobium* and PSB; T₉: N₀P₀K₀BF₀

Different levels of nitrogen with 60 kg P₂O₅ and 30 kg K₂O/ha with and without biofertilizers were found to be at par with respect to plant height in both years.

Dry matter production was significantly affected by different treatments during the years, 2012 and 2013. In general, dry matter production was higher in 2013 than 2012 except in T₄, T₇ and T₈ (Table 1). Statistically similar dry matter production was recorded at different levels of nitrogen plus 60 kg P₂O₅ and 30 kg K₂O/ha along with biofertilizers. In 2012, T₇ and T₈ produced similar dry matter production but higher than T₉. Significantly higher dry matter production was recorded with combined application of chemical fertilizers and *Rhizobium* and PSB biofertilizers as compared to control treatment. Based on the mean value of two years, maximum dry matter production (57.54 q/ha) was noted in T₆ while the minimum (31.77 q/ha) was in T₉. An increase of 81.11% dry matter production was observed in the treatment T₆ as compared to T₉.

Higher dry matter efficiency was recorded in 2013 as compared to 2012. Based on the mean value of two years, dry matter efficiency ranged from 0.37 (N₄₀P₆₀K₃₀) to 0.45 (N₀P₆₀K₃₀+seed inoculated with *Rhizobium* + PSB) percent/day. The treatment T₇ showed 15.38% higher mean dry matter efficiency over control treatment (T₉).

Like dry matter efficiency, higher unit area efficiency was recorded in the second year, 2013. Mean unit area efficiency increased with increasing level of nitrogen up to 60 kg/ha plus 60 kg P₂O₅/ha and 30 kg K₂O/ha (T₅). Integration of biofertilizers with chemical fertilizers also followed the same trend as nitrogen. Higher unit area efficiency was observed in integrated application of chemical fertilizer and biofertilizer than the application of chemical fertilizer only. Based on the mean value of two years, maximum UAE (23.57 kg/ha/day) was recorded in T₆ (N₆₀P₆₀K₃₀+seed

inoculated with *Rhizobium* and PSB) while minimum (13.28 kg/ha/day) was in T₉ (absolute control). The treatment T₆ resulted in 77.48% higher UAE than control treatment. Similar UAE was observed in the treatments inoculated with only biofertilizers and no chemical fertilizer (T₇ & T₈). The UAE in these treatments was higher than the control treatment (T₉).

Use of chemical fertilizers in combination with biofertilizers increases the availability of nitrogen, phosphorus and potassium along with other micro-nutrients (Sharma and Verma 2011 and Thakur *et al.* 1999). Nitrogen plays an important role in increasing vegetative growth while phosphorus and potassium improve root growth and grain quality, respectively. Potassium enhances availability of N and P. The application of biofertilizers increases fertilizer use efficiency in addition to stimulating the plant growth hormones providing better nutrient uptake and enhancing tolerance towards drought and moisture stress. These might be the reasons for higher dry matter production, dry matter efficiency and unit area efficiency. Thakur *et al.* (1999), Parmar *et al.* (1999), Kumar *et al.* (2005), Anandaraj and Delapierre (2010), and Sharma and Verma (2011) have also reported taller plants and higher dry matter production with combined application of chemical fertilizers and biofertilizers.

Yield attributing characters

The yield attributing characters (pod length, seeds/pod and 100-seed weight) were significantly influenced by the different treatment combinations during 2013. During 2012, pod length and seeds/pod were non-significant (Table 2). Values of pod length, seeds/pod and 100-seed weight were higher in 2013 as compared to 2012 except in T₇ and T₈.

Pod length significantly increased with increasing level

Table 2 Yield attributing characters and yield as influenced by combined application of chemical fertilizer and biofertilizer

Treatment	Yield attributing characters						Yield			
	Pod length (cm)		Seeds/pod		100-seed weight (g)		Seed yield (q/ha)		Straw yield (q/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
T ₁	12.73	12.80	3.90	4.50	50.17	51.50	16.91	19.24	29.16	33.26
T ₂	12.83	13.04	3.86	4.77	50.93	51.84	17.61	18.75	29.28	32.25
T ₃	12.76	13.77	4.03	5.03	50.13	54.43	18.08	19.37	34.41	34.75
T ₄	13.30	13.97	4.36	5.00	50.27	54.73	18.20	18.99	34.53	32.25
T ₅	13.70	14.47	3.73	5.15	54.15	54.90	17.50	20.62	30.91	33.75
T ₆	13.50	15.48	3.80	5.10	54.57	55.18	17.43	24.99	30.77	32.25
T ₇	13.40	12.52	3.60	4.40	49.20	47.15	16.33	17.37	28.58	32.25
T ₈	13.20	12.53	3.53	4.43	49.40	47.02	16.21	17.49	28.11	32.25
T ₉	12.27	11.06	3.36	3.73	42.03	42.03	10.15	13.75	18.29	21.35
CD(P=0.05)	NS	0.87	NS	0.67	6.08	1.55	2.85	4.59	5.91	6.25

T₁: N₂₀P₆₀K₃₀; T₂: N₂₀P₆₀K₃₀+ seed inoculated with *Rhizobium* and PSB; T₃: N₄₀P₆₀K₃₀; T₄: N₄₀P₆₀K₃₀+ seed inoculated with *Rhizobium* and PSB; T₅: N₆₀P₆₀K₃₀; T₆: N₆₀P₆₀K₃₀+ seed inoculated with *Rhizobium* and PSB; T₇: N₀P₆₀K₃₀+ seed inoculated with *Rhizobium* and PSB; T₈: N₀P₆₀K₃₀+ soil inoculated with *Rhizobium* and PSB; T₉: N₀P₀K₀BF₀

of nitrogen in combination with phosphatic and potassic fertilizers, *Rhizobium* and PSB. Significantly longer pods were recorded in T₆ followed by T₅. Shorter pods were observed in T₉. Based on the mean value of two years, an increase of 24.16% in pod length was observed in T₆ as compared to T₉.

Seeds per pod did not differ significantly during 2012. However, higher number of seeds/pod was found in the treatments with chemical fertilizers or chemical fertilizers and biofertilizers as compared to the control treatment. In 2013, significantly higher number of seeds per pod was recorded in T₅ followed by T₆, T₃, T₄, T₂ and T₁ as compared to T₇, T₈ and T₉. The lowest number of seeds per pod was noted in the absolute control treatment. The mean number of seeds per pod during the years 2012 and 2013 was maximum in T₄ and the value was 32.20% higher in T₄ as compared to T₉ based on the mean value of two years.

Seed index (100-seed weight) was significantly influenced by different treatment combinations during both the years (Table 2). Higher seed weight was observed in 2013 as compared to 2012. Combined application of chemical fertilizers and biofertilizers significantly enhanced the 100-seed weight. Based on the mean value of two years, the highest seed weight (54.90 g) was recorded in T₆ which was 30.71% higher as compared to the control treatment (T₉). Biofertilizers in combination with only 60 kg P₂O₅/ha and 30 kg K₂O/ha significantly increased the 100-seed weight as compared to absolute control.

The higher values of pod length, seeds/pod and 100-seed weight of rajmash in T₆ over T₉ may be due to the profuse vegetative growth induced by application of chemical fertilizers and microbial inoculants. This ultimately may increase the photosynthetic assimilation. All these physiological activities brought about increase in yield attributes. Similar findings have also been observed by Thakur *et al.* (1999), Turuko and Mohammed (2014), Kumar *et al.* (2005), Girma (2009) and Sharma and Verma (2011).

Yield

Seed yield and straw yield of rajmash were significantly affected by different treatments during both the years, 2012 and 2013. Like yield attributing characters, the seed and straw yield was higher in 2013 than 2012 (Table 2).

Seed yield increased with increasing level of chemical fertilizers in combination with biofertilizers, *Rhizobium* and PSB. In 2012, significantly higher seed yield was recorded in those treatments where both chemical fertilizers and biofertilizers were applied. The lowest seed yield was recorded in control treatment (T₉). Biofertilizers in combination of 60 kg P₂O₅ and 30 kg K₂O/ha also significantly increased seed yield as compared to control treatment. In 2013, the highest seed yield was noted in T₆ while the lowest was in T₉. Based on the mean value of two years, T₆ resulted in 81.75% higher seed yield than control treatment T₉ (Table 2). Seed and soil inoculated with *Rhizobium* and PSB with only 60 kg P₂O₅/ha and 30

kg K₂O/ha did not differ in respect of seed yield. Mean seed yield for both the years was 77.49% higher in T₆ as compared to T₉.

Significantly higher straw yield was recorded with the combined application of chemical fertilizers and biofertilizers as compared to absolute control in both the years except T₅ in 2012 and T₄ in 2013 (Table 2). Maximum straw yield of 34.53 q/ha and 34.75 q/ha was recorded in T₄ and T₃ during 2012 and 2013, respectively. Minimum straw yield of 18.29 q/ha and 21.35 q/ha was noted in T₉ during 2012 and 2013, respectively.

The increased yield might be attributed due to significant influence of nitrogen on translocation of nutrients and dry matter accumulation during reproductive stage which in turn improved growth and yield attributes, and ultimately seed yield and straw yield (Sharma *et al.* 2003, Singh *et al.* 2009). Srinivas and Rao (1984), Singh (1987), Verma and Saxena (1995), Rana *et al.* (2001), Sharma and Verma (2011), Hussaindar *et al.* (2014) and Singh and Dubey (2015) have also observed significant response of common bean to integrated use of chemical fertilizers and microbial inoculants in terms of seed yield and straw yield.

Higher mean value of harvest index was recorded in the treatment T₇ with the application of 60 kg P₂O₅/ha and 30 kg K₂O/ha in combination with *Rhizobium* and PSB biofertilizers as compared to the other treatments. The higher value of harvest index might be attributed due to increased availability of different nutrients particularly phosphorus which improves grain straw ratio of the crops.

Economics

The net returns and benefit cost ratio of different treatment combinations were numerically analyzed. The net returns and benefit cost ratio were recorded higher in 2013 than 2012. Based on the mean value of two years, the highest net returns were recorded in T₆ (₹ 140338/ha) while the lowest was in T₉ (₹ 51, 584/ha). T₆ resulted in 172.05% higher mean net returns than T₉. The maximum and minimum profitability of ₹ 1477 and ₹ 543/ha/day was recorded in T₆ and T₉, respectively. Like net returns and profitability, the highest benefit cost ratio was also observed in T₆ (2.86) which was 65.32% higher than T₉. The higher net returns and benefit cost ratio could be attributed due to increased yield with application of chemical fertilizers in combination with biofertilizers (Sharma *et al.* 2003, Rana *et al.* 2001 and Singh *et al.* 2009).

Based on the results obtained, it can be concluded that integrated use of 60 kg N/ha in combination with 60 kg P₂O₅/ha and 30 kg K₂O/ha along with seed inoculation with *Rhizobium* and phosphate solubilizing bacteria (T₆) proved to be the best treatment for increasing productivity and profitability of rajmash crop in cold desert region of North-western Himalayas.

ACKNOWLEDGEMENTS

The facilities and co-operation provided by Dr Janardan Singh, Associate Director, Highland Agricultural Research

and Extension Centre, Kukumseri, Lahaul and Spiti, Himachal Pradesh for the present investigation is thankfully acknowledged.

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