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Organic matrix based slow release fertilizer enhances plant growth, nitrate assimilation and seed yield of Indian mustard (*Brassica juncea* L.)

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Abstract

Field experiments were conducted to study the effect of organic matrix based slow release fertilizers (SRFs) on plant growth, nitrate assimilation and seed yield of *Brassica juncea* L. cv. pusa bold. The agro-waste materials like cow dung, clay soil, neem leaves and rice bran were mixed together in 2:2:1:1 ratio and used as organic matrix for the immobilization of chemical fertilizer nutrients with commercial grade saresh (*Acacia* gum, 15% solution) as binder. Different fertilizer treatments were organic matrix based slow release fertilizers, SRF-I (542.0 kg ha^{-1}); SRF-II (736.5 kg ha^{-1}) and chemical fertilizer combinations, boron (3 kg ha^{-1})+sulphur (15 kg ha^{-1})+nitrogen (80 kg ha^{-1}) and boron (3 kg ha^{-1}) + sulphur (15 kg ha^{-1})+nitrogen (80 kg ha^{-1})+phosphorus (15 kg ha^{-1})+potassium (100 kg ha^{-1}). Organic matrix based SRF-II released ammonium up to 50-d in wet soil under laboratory conditions which showed maximum retention of the nutrients. A very significant increase in plant growth, nitrate assimilation and seed yield was recorded in organic matrix based SRF-II applied plants. The maximum percent increase in biomass production was observed with organic matrix based SRF-II (increase of 65.8% in root fresh weight, 38.0% in root dry weight, 45.9% in leaf fresh weight plant^{-1} and 27.5 % in leaf dry weight plant^{-1} in 60-d old plants). It also increased the acquisition and assimilation of nitrate from the plant's rhizosphere which was evident by 45.6% increase in nitrate, 27.5% in nitrite and 11.7% in nitrate reductase activity (NRA) in leaves of 45-d old plants over control. The organic matrix based SRF-II significantly increased the seed yield by 28% in Indian mustard. Cost analysis revealed that this formulation is cost effective as it is based on agro waste materials.

Key words

Chemical fertilizer, Organic matrix, Slow release fertilizer, Seed yield, *Brassica juncea*

Introduction

Brassica juncea L. Czern and Coss (Indian mustard) is an important oilseed crop in South East Asia and is second after groundnut in India in terms of acreage and productivity (Damodaran and Hedge, 2005). India occupies first position in area and fourth in production of mustard seed contributing 23 and 14% in world area and production respectively. Mustard seed covered an area of 6.4 million ha during the year 2009-2010 with a production of 6 million tonnes at the rate of 920 kg ha^{-1} yield in India (USDA, 2010). To meet the minimal nutritional requirement of fat and oils (12 kg capita^{-1} yr^{-1}) and for other uses, it has been estimated that nearly 24 million tonnes of rapeseed and mustard are required by 2020 A.D. (Shukla *et al*., 2005). Nitrogen, sulfur and boron fertilization has significantly enhanced growth and yield of *B. juncea* in the Indian soil (Nema *et al.*, 2008). However, a major portion of the applied chemical nitrogen fertilizers is lost through the leaching, run off, emissions and volatilizations which cause economic losses and serious environmental problems (Singh *et al.,* 2006; Abdin *et al*., 2006; Galloway *et al*., 2008; Singh *et al*., 2010). Farm yard manure (FYM) and bio-fertilizers are used for eco-friendly organic farming, however they are unable to replace chemical fertilizers in terms of crop productivity.

The slow release fertilizers are slow acting and facilitate long term availability of the nutrients often synchronized with the physiological need of plants and are considered as one of the most viable alternative for the sustainable plant productivity (Dahiya *et al*., 2004; Kavoosi, 2007; Ingle *et al*., 2010; Taoukis and Assimakopoulos, 2010). Certain reports are available regarding use of slow release fertilizers for oilseed crops, however, either the yield increased has not been found significant or the cost of fertilizers does not permit farmers in the countries like India to replace chemical fertilizers (Ombodi *et al*., 2000; Ahmad *et al*., 2001; Amkha and Inubushi, 2009). In present study, organic matrix based slow release fertilizer enhances plant growth, nitrate assimilation and seed yield of Indian mustard and is cost effective.

Materials and Methods

Preparation of organic matrix based SRF granules: The agro-waste materials such as cow dung, clay soil, neem leaves and rice bran were collected, dried and mixed in their powdered forms in a specific ratio (2:2:1:1) to prepare organic matrix based slow release fertilizer granules (SRF-I and SRF-II). The various components of different treatments including chemical fertilizers and organic matrix based SRF granules have been described in Table 1. The organic matrix based SRF granules (diameter=0.5 mm) were prepared manually and stored in poly bags for further use in experimental plots.

Estimation of release of ammonium from organic matrix based SRF granules: The soil sample (250 g) was taken in a magenta box and it was wet with distilled water (DW). One granule of organic matrix based SRF was dipped in the wet soil and added 10 ml of DW with it to allow the release of ammonium. The released ammonium in wet soil was extracted routinely and was estimated under laboratory conditions following the method described by Weatherburn, (1967).

Preparation of experimental plots and treatment schedule: The experiments were conducted in the field plots, under natural conditions at Lucknow during two consecutive crop seasons (October to March, 2005/06 and 2006/07). Lucknow is situated at 123 m above sea level on 26.30° and 27.10° N latitude and 80.30° and 81.13° E longitudes. The experimental plots of 2-square feet area were maintained for cultivation of *B. juncea* L. cv. pusa bold. The experimental design consisted of five different treatments and each treatment was applied in triplicate in a randomized block design (RBD). The single basal dose of organic matrix based SRF granules (SRF-I, 542.0 kg ha^{-1} and SRF-II, 736.5 kg ha^{-1}) was applied to the field plots. The basal doses of organic matrix based slow release fertilizer granules differ because SRF-II contains additional chemical nutrients (P and K) as compared to SRF-I. However, chemical fertilizers were supplied in two split doses at 0 and 20-d. The split doses of chemical fertilizers were exactly half (B = 1.5, S = 7.5, N = 40, P = 7.5 and K = 50 kg ha^{-1}) of the recommended dose (Table 1).

Measurement of plant growth, nitrate assimilation and seed yield: Plant growth parameters like root biomass in terms of root fresh and dry weights and shoot biomass in terms of leaf fresh and dry weights per plant were measured routinely at 15, 30, 45 and 60-d after sowing. Similarly nitrate assimilation in plant leaves was studied by estimating leaf nitrate (Catalado *et al*., 1975), nitrite (Steven and Oaks, 1973) and nitrate reductase activity (Kadam *et al*., 1980) at different days. Various seed yield attributes like number of siliquae per plant, number of seeds per siliqua, 1000-seed weight (g) and seed yield (q ha^{-1}) were recorded from each field block after its proper winnowing.

Cost analysis: The cost of cultivation for each treatment understudy was worked out for detailed assessment of the cost involved and net gains. The cost calculation was carried out on the basis of prevailing market rates during both the crop years. The details of cost benefits have been described in Table 3.

Statistical analysis: The data presented are mean values of six replicates ± SE from two subsequent years having three independent replicates each year for each treatment. One way ANOVA with randomized block design and multiple comparison tests were applied for statistical analysis.

Results and Discussion

Release of ammonium from organic matrix based SRF granules: The release of ammonium was observed up to 50-d from organic matrix based SRF-II followed by SRF-I up to 40-d in wet soil under laboratory conditions (Fig.1). However, ammonium release was observed up to 30-d only in wet soil applied with recommended dose of chemical fertilizers. Only trace amount of ammonium was found in the soil having no fertilizer application. Organic matrix based SRF-II showed longer retention of ammonium probably due to its immobilization in organic matrix bound with commercial saresh (*Acacia* gum, 15% solution) as well as its release from the organic matrix itself. Ammonium was available for longer duration that synchronized with the nitrogen demand of the *Brassica* plants due to the slow release property of organic matrix based SRF granules.

Organic matrix contains cow dung and rice bran which are rich source of mineral nutrients, clay soil that bind strongly to organic

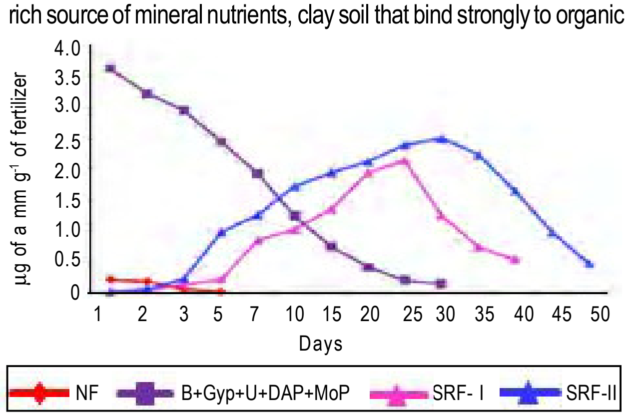

Fig. 1: Release of ammonium in wet soil under laboratory conditions of different treatment on days 1 to 50

Table - 1: Details of different treatments of chemical fertilizers and organic matrix based slow release fertilizer (SRF) granules

Treatments	Composition and application
B+Gyp+U+DAP+MoP; Chemical fertilizers (Control)	Boron (3 kg ha^{-1})+Sulfur (15 kg ha^{-1})+ Nitrogen (80 kg ha^{-1})+Phosphorus (15 kg ha^{-1})+Potassium (100 kg ha^{-1}) applied in two split doses (TSD)
No fertilizer	None of the fertilizers used
B+Gyp+U; chemical fertilizers	Boron (3 kg ha^{-1})+ Sulfur (15 kg ha^{-1})+ Nitrogen (80 kg ha^{-1}) applied in two split doses (TSD)
Organic matrix based SRF-I	Boron (1.5 kg ha^{-1})+ Sulfur (7.5 kg ha^{-1})+ Nitrogen (40 kg ha^{-1})+Matrix; cow dung, clay soil, neem leaf powder and rice bran in 2:2:1:1 ratio (356 kg ha^{-1}) immobilized with 15% saresh (8.0 kg ha^{-1}) (gum *Acacia*); The SRF granules were applied @542.0 kg ha^{-1} as basal dose.
Organic matrix based SRF-II	Boron (1.5 kg ha^{-1})+Sulfur (7.5 kg ha^{-1})+ Nitrogen (40 kg ha^{-1})+ Phosphorus (7.5 kg ha^{-1})+Potassium (50 kg ha^{-1})+Matrix; cow dung, clay soil, neem leaf powder and rice bran in 2:2:1:1 ratio (483.8 kg ha^{-1}) immobilized with 15% saresh (10.8 kg ha^{-1}) (gum *Acacia*); The SRF granules were applied @736.5 kg ha^{-1} as basal dose.

B = Boric acid, Gyp = Gypsum, U = Urea, DAP = Diammonium phosphate, MoP = Muriate of potash

Table - 2: Effect of chemical fertilizers and organic matrix based slow release fertilizer granules on seed yield attributes of *Brassica juncea* grown in natural field conditions

Treatments	No. of siliqua / plant	No. of seeds/ siliqua	1000 seed weight (g)	Seed yield (q ha^{-1})
B+Gyp+U+DAP+MoP; Chemical fertilizers (Control)	$206.6^{c}\pm0.494$ (100.0)	$12.4^{b}\pm0.210$ (100.0)	$5.2^{c}\pm0.01$ (100.0)	$23.5^{c}\pm0.421$ (100.0)
No Fertilizer	$90.4^{d}\pm0.494$ (43.1)	$6.4^{d}\pm0.600$ (51.5)	$3.4^{e}\pm0.06$ (65.3)	$17.4^{e}\pm0.600$ (74.0)
B+Gyp+U; Chemical fertilizers	$192.2^{c}\pm0.577$ (93.0)	$10.0^{c}\pm0.428$ (80.6)	$4.6^{d}\pm0.05$ (88.3)	$20.2^{d}\pm0.421$ (85.9)
Organic matrix based SRF-1	$230.4^{b}\pm0.494$ (111.5)	$13.5^{b}\pm0.258$ (108.8)	$6.4^{b}\pm0.17$ (122.8)	$27.2^{b}\pm0.670$ (115.7)
Organic matrix based SRF-II	$254.2^{a}\pm0.966$ (123.0)	$15.2^{a}\pm0.223$ (122.5)	$7.8^{a}\pm0.04$ (149.7)	$30.2^{a}\pm0.254$ (128.4)

The values are mean of six replicates. Values in parentheses are % change over the control (100). The data was analyzed by one-way ANOVA at least significant difference (LSD)<0.05. Statistically significant differences have been shown by different alphabets

Table - 3: Net loss/gain in terms of economic return for Indian mustard cultivated using various kinds of fertilizers

	Input cost (Rs.) ha^{-1}			Income (Rs.) ha^{-1}		
Treatments	Fertilizer cost	Others	Total	Net seed yield (q ha^{-1})	Cost of product	Net loss gain^{-1} (-/+)
B+Gyp+U+DAP+MoP (Control)	3,628/-	1000/-	16,188/-	23.5	65,800/-	49,612/-
No fertilizer	0	1000/-	12,560/-	17.4	48,720/-	36,160/-
B+Gyp+U	1,650/-	1000/-	14,210/-	20.2	56,560/-	42,350/-
Organic matrix based SRF-1	8,316/-	45,00/-	24,376/-	27.2	76,160/-	51,784/-
Organic matrix based SRF-II	11,922/-	45,00/-	27,982/-	30.2	84,560/-	56,578/-

Input cost of labour and field preparation = Rs. 10,000/- , Cost of seed sowed per hectare = Rs. 1,560/-, Approximate rate of mustard seed/quintal = Rs. 2800/-

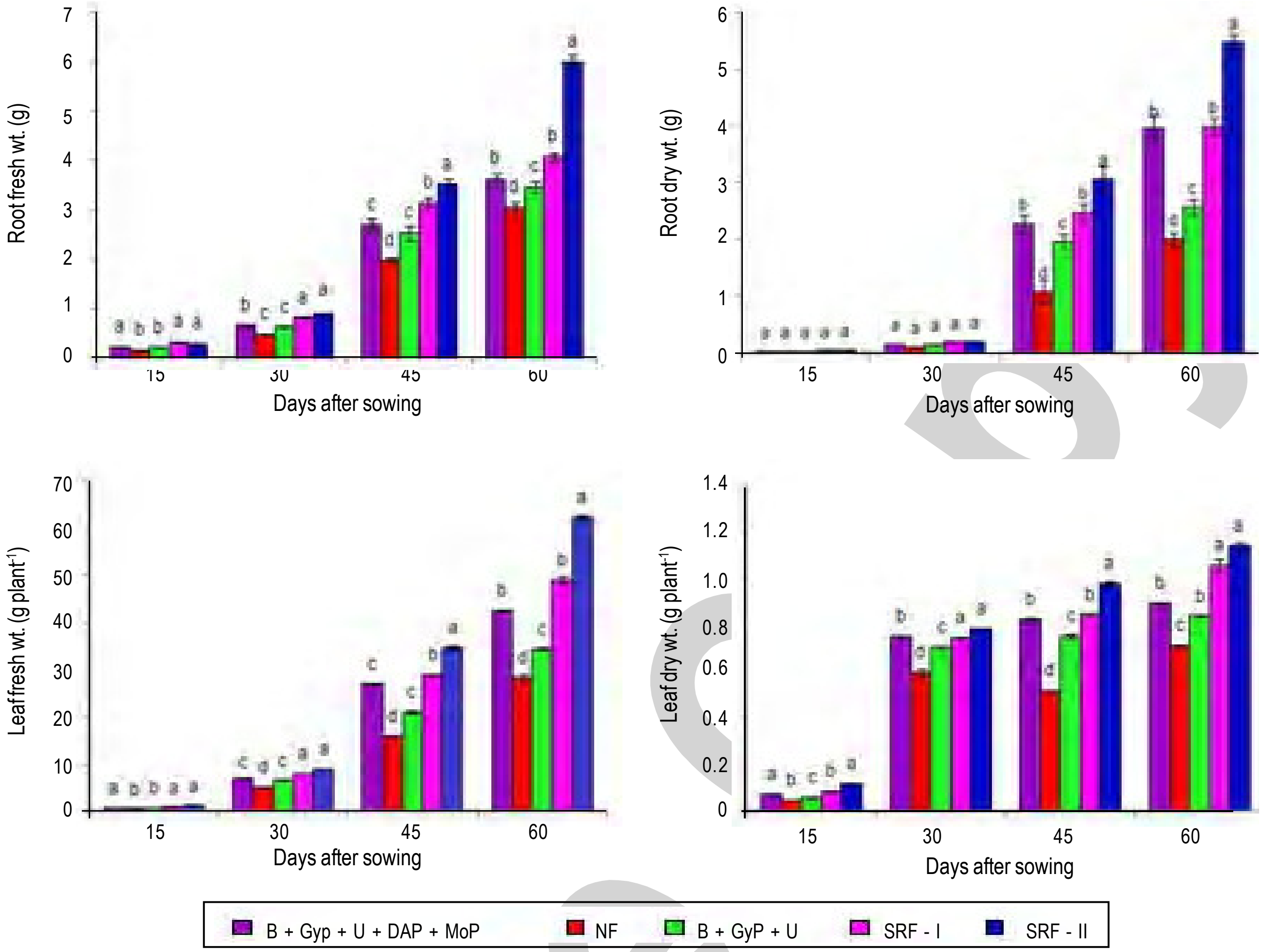

Fig. 2: Effect of organic matrix based SRF granules on root and shoot growth in *Brassica juncea*. The values are mean $\pm$S.E. of six replicates. The data was analyzed by one way ANOVA at LSD<0.05. Statistically significant differences have been shown by different alphabets

matrix and retain ammonium for longer duration (Verkaik *et al*., 2006), and neem leaves contained nitrification inhibitor, which also stabilizes the degradation of organic nitrogen forms (Puri, 1999). Slow release fertilizers are known to reduce nitrogen leaching in different type of soils (Saigusa, 1999; Entry and Sojka, 2008). The coated nitrogen fertilizers have shown slow release property (Saigusa, 1999; Liang and Liu, 2006) and controlled release nitrogen fertilizers have shown different slow release patterns of nitrogen to synchronize nitrogen supply from the polymer coated urea fertilizers with the nitrogen demand patterns of rice varieties (Kabat and Panda, 2009).

Effect of organic matrix based SRF granules on plant growth, nitrate assimilation and seed yield: Growth of Indian mustard at 15, 30, 45 and 60-d increased significantly in terms of root and shoot biomass when applied with organic matrix based SRF granules. In case of root growth, the maximum percentage increase of 65.8% in root fresh weight and 38.0% in root dry weight was recorded in 60-d old plants treated with organic matrix based SRF-II followed by 12.7 and 0.7% increase in 60-d old plants with organic matrix based SRF-I over the control (recommended dose of chemical fertilizers applied in two split doses) (Fig. 2). In case of shoot growth, the maximum percentage increase in leaf fresh weight and leaf dry weight was found to be 45.9 and 27.5% with organic matrix based SRF-II followed by 18.6 and 14.9% with organic matrix based SRF-I respectively in 60-d old plants over the control (Fig. 2).

Nitrate assimilation in leaves of *Brassica juncea* was affected significantly in organic matrix based SRF granules treated plants at different growth stages. The maximum percentage increase of 45.6% in nitrate and 11.7% in nitrite contents was found in 45-d old plants with organic matrix based SRF-II followed by 26.4 in 45-d old plants and 3.5% in 60 d old plants applied with organic matrix based SRF-I respectively over the control (Fig. 3). In case of nitrate reductase activity (NRA), maximum percentage increase of 27.5% was recorded in SRF-II applied plants followed by 20.0% in SRF-I applied 45-d old plants respectively over the control.

Our data indicate significant increase in seed yield attributes with the treatment of organic matrix based SRF granules, SRF-I

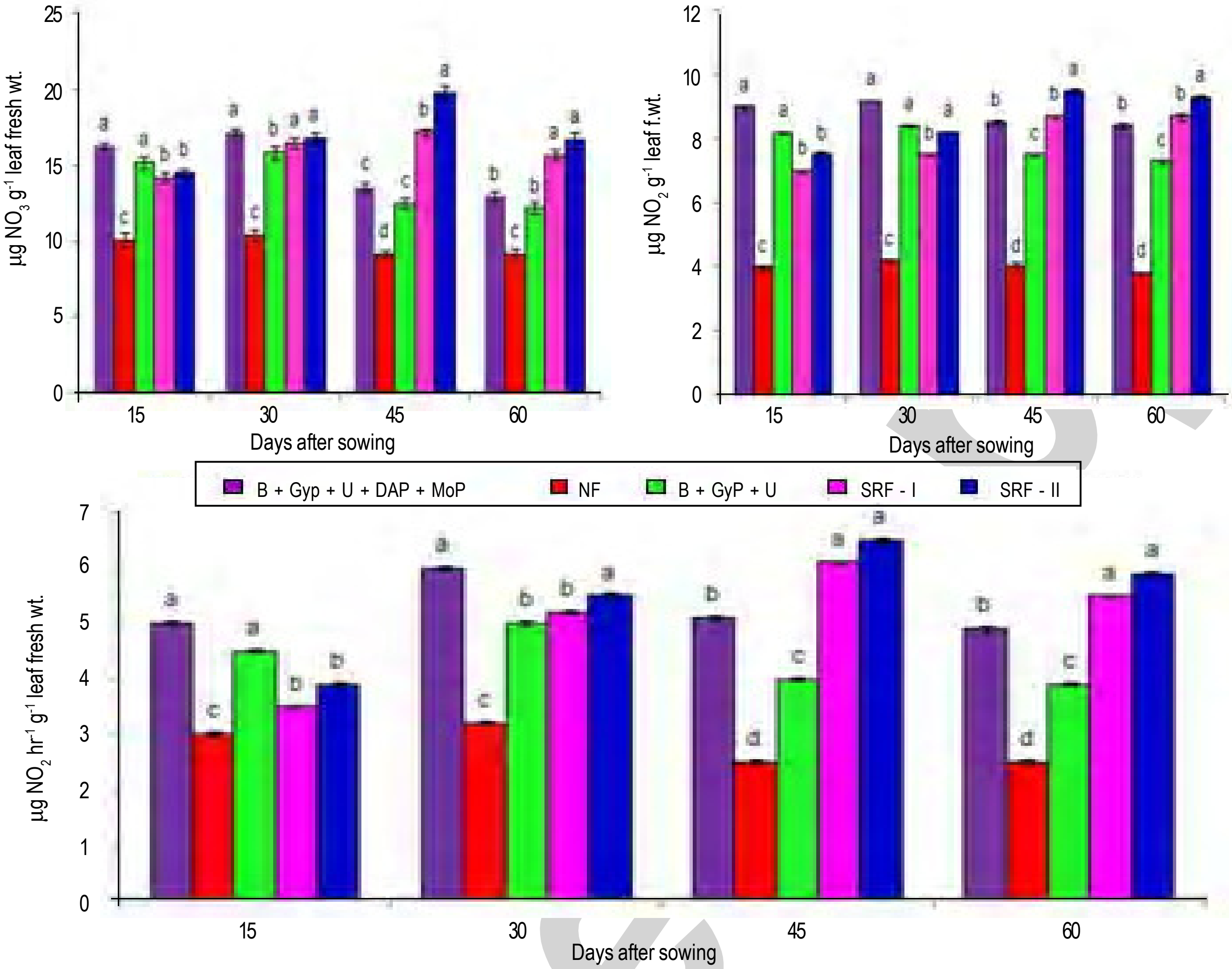

Fig. 3: Effect of organic matrix based SRF granules on nitrate assimilation in leaves of *Brassica juncea*. The values are mean ± SE of six replicates. The data was analysed by one way ANOVA at LSD<0.05. Statistically significant differences have been shown by different alphabets

and SRF-II (Table 2). The maximum percentage increase of 23.0% in number of siliquae per plant and 22.5% in number of seeds per siliqua was recorded in SRF-II applied plants followed by 11.5 and 8.8% in SRF-I applied plants respectively over the control. In case of 1000-seed weight and seed yield, the maximum percentage increase of 49.7 and 28.4% was observed with the application of SRF-II followed by 22.8 and 15.7% with SRF-I respectively as compared to the control.

The organic matrix based SRF granules significantly enhanced plant growth, nitrate assimilation and seed yield of *Brassica juncea* plants over the plants applied with recommended dose of soluble chemical fertilizers (control). The organic matrix based SRF-II showed highest plant growth and seed yield amongst other treatments. The plant growth consistently enhanced as a function of age of the plants as measured on 15, 30, 45 and 60 days after sowing. The plants which kept deprived for any kind of additional fertilizer showed a reduced growth and yield. Non-availability of DAP and muriate of potash, even caused a reduction in plant growth and seed yield. The organic matrix based SRF granules consistently supplied nutrients to Indian mustard plants with their demand at all stages of growth. Higher nitrate levels in plant leaves show better absorption of nitrogen by roots. Significantly higher nitrite levels and nitrate reductase activity in organic matrix based SRF-II treated plant leaves show increased nitrate assimilation at vegetative and reproductive stages that enhanced plant growth and seed yield. An increase in plant growth, nitrate assimilation and yield in many crops have been reported with the application of slow release fertilizers, which include tender green mustard (Ombodi and Saigusa, 2000), oil palm (Sidhu *et al*., 2000), long leaf pine (Dumroese *et al*., 2005), tomato (Nakano *et al*., 2003; Taoukis and Assimakopoulos, 2010), rice (Saigusa, 1999; Dahiya *et al*., 2004; Singh *et al*., 2006) , wheat (Ingle *et al*., 2010), bellpepper (Guertal, 2000), bean plants (El-Tohamy, 2009) and *Brassica napa* (Amkha and Inubushi, 2009). The slow release fertilizer provides nutrient for longer period in the quantity required for plant growth and productivity and reduces the leaching, runoff and volatilizational losses of the nutrient and therefore increases the efficiency of plant nutrients in an eco-friendly manner.

Our formulation is cost effective as it is based on the local agro-waste materials (Table 3). The total cost of cultivation was calculated by detailed economic analysis of input cost and income obtained and it was the sum of common and variable costs of different treatments. The cost calculation of Indian mustard cultivation showed that organic matrix based SRF-II gave maximum net returns of Rs. (+) 56578.0/- ha^{-1} followed by Rs. (+) 51784/- ha^{-1} with SRF-I. The least net returns were recorded in the field plots having no additional fertilizer. Hence, this formulation can be used for sustainable productivity of Indian mustard; a significant oilseed crop of Indian subcontinent.

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