



Growth physiology of *Brassica rapa* var. yellow sarson under integrated nutrient management and seed soaking approaches in eastern sub-Himalayan plains

Saikat Mookherjee*, Ganesh Chandra Malik¹, Subhendu Bandyopadhyay and Biplab Mitra

Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar -736165 (West Bengal), INDIA

¹ Palli Siksha Bhavana, Institute of Agriculture, Visva-Bharati, Sriniketan-731236 (West Bengal), INDIA

*Corresponding author. E-mail: s.mookherjee@live.com

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Abstract: The field experiment was conducted at Uttar Banga Krishi Viswavidyalaya, West Bengal, India during *rabi* 2007-08 to 2008-09 to study the growth and productivity of yellow sarson under different nutrient management practices and pre-sowing seed soaking. The highest value of LAI (4.00), apart from the maximum plant height (129.97cm), dry matter accumulation (481.93g m⁻²) at 90 days, crop growth rate (12.29 g m⁻² day⁻¹) in between 45 to 60 days, root dry weight (1.645 g plant⁻¹) with the highest average root diameter (0.932 mm) were observed in treatments receiving 75% recommended dose of chemical fertilizer with farm yard manure, *Azotobacter* and phosphate solubilizing bacteria as non-chemical source. Similarly at 45 days of crop age, significantly higher stomatal conductance (701.68 m mol m⁻² s⁻¹) and transpiration rate (4.55 m mol m⁻² s⁻¹) were reflected by the same treatment combination. These were attributed to the production of maximum seed yield (1374 kg ha⁻¹), which was 39.91% higher than the recommended dose of chemical fertilizer application. On an average, seeds soaked with water before sowing reflected 9% lesser yield (1103 kg ha⁻¹) against chemical soaking. Yellow sarson crop grown with integrated nutrient management practice consisting 75% of the recommended dose of chemical fertilizer along with farm yard manure (5t ha⁻¹), *Azotobacter* (5kg ha⁻¹) and phosphate solubilizing bacteria (5kg ha⁻¹) coupled with seed soaking in 100ppm KH₂PO₄ confirms to be the best treatment combination from the treatment schedule considered during the study for the sub-Himalayan plains of West Bengal, India in terms of crop growth and productivity.

Keywords: Growth attributes, Nutrient uptake, Root growth, Seed yield, Yellow sarson

INTRODUCTION

Rapeseed-mustard group of crops is among the oldest cultivated plants in human civilization. It was cultivated by ancient civilization in Asia and Mediterranean. Its use has been recorded as early as 2000BC in India (Colton and Potter, 1999). It is a group of oilseed crops which assumes the significance in Indian national economy by occupying the second position next to groundnut and is considered as a 'cash crop'. Biologically, the rapeseed and mustard plants belongs to the family *Cruciferae* and under the genus *Brassica* with large number of species and sub species cultivated in India. Rapeseed-mustard (*Brassica spp.*) is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeis guineensis*) (Shekhawat *et al.*, 2012). Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total production of oilseed. This energy rich crop plays an important role in human nutrition and animal feed, occupying a key position in the diet of Indian masses. Rapeseed-mustard (*Brassica spp.*) is a common *rabi* crop cultivated over 8000 ha in the sub-Himalayan plains of West Bengal, India.

Though rapeseed-mustard is the major oilseed of this region, the productivity is very poor (491 kg ha⁻¹) compared to the state average productivity (889 kg ha⁻¹). This declination in productivity might be due to use of sub-optimal dose of fertilizers and lack of use of sufficient amount of organic matter in the nutrient management practices and this is also to be a major reason for decline in fertilizer use efficiency (Bourguignon, 2005). Sometimes poor and uneven crop establishment is also responsible for lower seed yield of this oilseed crop. Maintaining a uniform crop stand is also a challenge in the eastern sub-Himalayan plains (Islam *et al.*, 2013).

Recent advances in agriculture are focused on the reduction of the use of inorganic fertilizers, search for alternative ways to improve crop yield in sustainable agriculture. In spite of its efficiency in promoting crop yields chemical fertilizers have proved to be hazardous for soil health and well being of human and animal populations. So to maintain long-term soil health and crop productivity in intensive cropping system have underlined the need for integrated nutrient management practice comprising chemical fertilizers, organic manures, bio-fertilizers etc. (Hegde *et al.*,

1999). On the other hand pre-sowing seed priming not only homogenizes a seed lot, but this practice also gives a good crop stand to combat the adverse field condition. Seed priming also enhances metabolic activities and respiration rates by activating of enzymes involved in metabolism of seed reserves (Mauromicale and Cavallro, 1995), which gives a seed an earlier and increased germination, better and uniform field establishment. Improved emergence, dry matter accumulation as well as increased seed yield in rapeseed-mustard can be achieved through treating the seeds before sowing (Paul *et al.*, 1999). Keeping fertility and seed-soaking factors in mind this field experiment was under taken to study the growth pattern, ability of nutrient uptake and ultimately the seed yield of the yellow sarson, the popular oilseed crop of the sub- Himalayan plains.

MATERIALS AND METHODS

The experiment was carried out during two consecutive years *viz. rabi*, 2007-08 and 2008-09 at Uttar Banga Krishi Viswavidyalaya, situated at the sub-Himalayan plains West Bengal, India, with different treatment combinations tested on yellow sarson (*Brassica rapa* var. *yellow sarson*). The experimental soil was slightly acidic in reaction (pH 6.14), sandy loam in texture having mineralizable N (216.38 kg ha⁻¹), available P₂O₅ (46.52 kg ha⁻¹), available K₂O (147.45 kg ha⁻¹) and available SO₄⁻² (35.20 kg ha⁻¹). The experiment was laid out in factorial randomized block design with twenty four treatment combinations and replicated thrice. The treatments comprised of the different integrated nutrient management practices *viz.* 60:30:30 Kg N-P₂O₅ -K₂O ha⁻¹ as recommended dose; 100% recommended dose + 20 kg ha⁻¹ Sulphur; 75% recommended dose + 5t ha⁻¹ farm yard manure; 75% recommended dose + 5t ha⁻¹ vermicompost; 75% recommended dose + 5t ha⁻¹ farm yard manure + 5 kg ha⁻¹ *Azotobacter*; 75% recommended dose + 5t ha⁻¹ farm yard manure + 5 kg ha⁻¹ phosphate solubilizing bacteria; 75% recommended dose + 5t ha⁻¹ farm yard manure + 5 kg ha⁻¹ *Azotobacter* + 5 kg ha⁻¹ phosphate solubilizing bacteria and 75% recommended dose + 5t ha⁻¹ farm yard manure + 20 kg ha⁻¹ Sulphur. Seeds soaked with water and agro-chemicals (100ppm Na₂HPO₄ and 100ppm KH₂PO₄) have also been used as the treatments. In treatment combinations under the study, the organic manure were applied along with chemical fertilizers and bio-fertilizers, based on blanket application *in lieu* of nutrient content as the nutrient content in organic manure varies widely with location, raw materials and production process. Use of secondary nutrient like S, has also been included in the treatment combination considering the higher requirement of S by yellow sarson. The variety chosen for the experiment was NC-1, popularly known as *Jhumka*. It takes about 95-100 days to mature, seed colour is yellow. Fertilizers were applied in the plots as

per treatments just after laying out of the experiment. Nitrogen and potash were applied as basal and top dressing. Nitrogen was applied in two splits (half as basal and rest half as top dressing at 37 and 39 days after sowing during two years of experimentation), while three-fourth potassium was applied during final land preparation with one-fourth as top dressing at the same time of application of nitrogen. Entire phosphatic fertilizers were applied as basal. The source of P was di-ammonium phosphate, while the same fertilizer and urea along with muriate of potash were served as the sources of N and K respectively. Sulphur was applied in the form of elemental sulphur just after the application of chemical fertilizers as per the treatment schedule and mixed thoroughly with soil. Boron was applied in each plot equally in the form of borax @10 kg ha⁻¹. Well decomposed farm yard manure, vermicompost, *Azotobacter* and phosphate solubilizing bacteria were applied as per treatments and mixed thoroughly with the soil sixth and fifth days of application of chemical fertilizers and sulphur in the first and second year respectively. For the seed soaking treatments, solutions were prepared by dissolving 0.1 g of Na₂HPO₄ either or KH₂PO₄ in distilled water and volume was made up to 1000 ml. Keeping the seed rate of yellow sarson as 6.0 kg ha⁻¹, the seed rate for the each experimental plot sized 12 sq.m was calculated and that quantity of seeds were placed in different containers used for different plots and treatments accordingly. After that the seeds were soaked with water, Na₂HPO₄ and KH₂PO₄ as per the treatment schedule and allowed to absorb moisture up to 35% of their weight and kept in imbibed condition for 6 hrs and the seeds were then spread out in a thin layer for drying under shade before sowing. The sowing was done on November 03 and October 31 in the first and second year of experimentation respectively. Seeds were sown in lines in both the years with the help of duck foot tyne by opening a shallow furrow at uniform depth (2.5 to 3.0 cm), keeping the rows 30 cm apart. The seeds were covered immediately after sowing. For maintaining appropriate plant to plant distance, thinning was done. In both the years, thinning was performed once at 14 days after sowing. Light irrigation (2-3cm) was given to the yellow sarson crop at 37 and 39 days after sowing in the first and second year respectively. Each experimental plot was divided in to two equal halves. One half was kept undisturbed for determining yield and remaining half was used for recording biometrical observations including destructive samples. Leaf area index (LAI) was obtained by using area-weight relationship where leaf areas of dried leaf samples were worked out (Kemp, 1960). Leaf area duration is a measure of the ability of the plant to produce leaf area on unit land area throughout its life. Leaf area duration was calculated by the following formula.

$$\text{LAD} = \frac{L_2 - L_1}{\text{Loge } L_2 - \text{Loge } L_1} \times t \text{ (days)}$$

Where, L_2 and L_1 are the final and initial leaf area indices at respective time.

Plant heights were measured with a meter scale from ground level to the tip of the main stem. No. of primary branches were recorded simply by counting method. To record dry matter accumulation the sampled plants were separated in to leaves, stem, root and reproductive parts, then the samples were oven dried at 65°C to 70°C till constant weight were obtained. Those weights were then converted in to weight m^{-2} taking into consideration the row spacing. The crop growth rate was measured using following formula.

$$\text{Crop growth rate} = \frac{w_2 - w_1}{t_2 - t_1} \text{ (g m}^{-2} \text{ day}^{-1}\text{)}$$

Where, w_1 and w_2 were the initial and final dry weights of all the plant parts per unit area at times t_1 and t_2 respectively.

Stomatal conductance, transpiration rate and net photosynthesis rate (NPR) of yellow sarson were recorded at 45 days after sowing in both years by hand held portable photosynthesis system (model no. CI-340) on the third available leaf from the top between 12 noon to 1 pm. To measure average diameter, total root length of the yellow sarson plants, randomly selected representative ten plants from all the treatments were studied during maturity with Delta T Scan (splash cover) by lifting plants from each plot with the help of a spade without damaging the root system and the root dry weight $plant^{-1}$ was measured after oven drying the root samples at 65°C to 70°C till constant weights were recorded. The crop was harvested plot wise on February 16, 2008 for the first year of experiment and on February 15, 2009 for the second year of experiment. All the data have been recorded here as the pooled of the two years of experimentation. For estimating uptake of nutrients the plants were analyzed. Plant nitrogen content was estimated by digestion with concentrated H_2SO_4 and distillation process (Jackson, 1973), Plant phosphorus and potassium content was estimated by Tri-acid digestion process (Jackson, 1973) and the plant sulphur by Turbidimetry method as described by Chesnin and Yien(1951). The statistical analysis of data was done following the procedure for analyzing factorial randomized block design and by using statistical software MSTAT-C version 2.1(Michigan State University, USA). Significant differences between the treatments were compared with the critical difference at $\pm 5\%$ probability by least significant difference.

RESULTS AND DISCUSSION

The results of the experiment indicated that the leaf area index (LAI) at the different growth stages, total leaf area duration, plant height and the number of primary branches $plant^{-1}$ of yellow sarson were significantly influenced by the different nutrient management practices (Table 1). The highest value of

leaf area index (4.00) was recorded at 60 days after sowing where the crop received 75% of the recommended dose along with farm yard manure, *Azotobacter* and P.S.B. This was in line of conformity with the findings of Mir (2003). This was also noticed that this nutrient management practice was helpful in maintaining higher values of LAI throughout the growing period, which ultimately reflected in to the integrated leaf area index over time *i.e.* total leaf area duration (128.17 days). Plant height also increased markedly due to combined application of 75% recommended dose farm yard manure + *Azotobacter* + P.S.B (139.97 cm) over the 100% recommended dose (116.48 cm) recorded at the maturity stages. The number of primary branches $plant^{-1}$ followed the same trend. Similar trend of results was also found in Indian mustard by Patel and Shelke (1998). Both the seed soaking agro-chemicals showed significantly greater impact over the water soaked seeds on LAI, leaf area duration, plant height and number of primary branches. Significant increase in LAI at 60 DAS (3.72), total leaf area duration (118.43 days), plant height (133.21 cm) and number of primary branches $plant^{-1}$ (5.83) were recorded where the yellow sarson seeds were soaked with 100ppm KH_2PO_4 compared to water soaked seeds, but these values were statistically at par with the values where the seeds were soaked with 100 ppm Na_2HPO_4 . Irrespective of treatments, the leaf area index increased steadily up to 60 days after sowing, and then it declined rapidly due to senescence of leaves as the crop progressed towards its maturity. The first pre-requisite for high yields of crop plants is a high production of total dry matter per unit area.

The amount of dry matter production depends on photosynthesis which in turn depends on large and efficient assimilating area, adequate supply of solar radiation and carbon di-oxide and favourable chemical conditions. An amount of photosynthates are used in respiration which is essential for maintenance and development. The total yield of dry matter is, therefore, the amount of dry matter produced less the photosynthates used for respiration. Finally, the amount of economic yield depends on the manner in which the net dry matter produced is distributed among the different parts of the plant. The results showed (Table 2) that dry matter production increased gradually and progressively till 90 days after sowing and thereafter at the harvesting stage a slight decrease in dry matter have been observed in all the treatments applied. Decrease in dry matter accumulation after 90 days after sowing was due to senescence of dried leaves and some of the other dried plant parts. Dry matter production at different growth stages varied significantly due to the different levels of nutrient management practices. High dry matter accumulation at the combined application of 75% of recommended dose of chemical fertilizer along with farm yard manure and both the bio-fertilizers (*Azotobacter* and P.S.B) was the

Table 1. Effect of INM and pre-sowing seed soaking on LAI, total LAD, plant height and No. of primary branches plant⁻¹ of *B. rapa*.

Fertility levels	LAI				Total leaf area duration (days)	Plant height (in cm) at 90 DAS	No. of primary branches plant ⁻¹
	30 DAS	45 DAS	60 DAS	75 DAS			
Recommended dose	0.56	1.93	3.30	1.50	105.15	116.48	4.86
100%RD+ Sulphur	0.58	1.95	3.32	1.58	107.76	120.05	5.00
75%RD+FYM	0.57	2.01	3.59	1.75	114.10	129.27	5.21
75%RD+Vermicompost	0.62	2.09	3.75	1.79	119.02	132.17	5.58
75%RD+ FYM +Azotobacter	0.62	2.15	3.80	1.83	122.26	134.34	6.21
75%RD+ FYM +P.S.B	0.62	2.06	3.75	1.82	119.48	133.04	6.16
75%RD+ FYM +Azotobacter+P.S.B	0.64	2.21	4.00	1.97	128.17	139.97	6.96
75%RD+ FYM +Sulphur	0.60	2.00	3.61	1.73	113.21	129.86	5.31
S.Em (±)	0.01	0.05	0.10	0.05	2.79	3.02	0.16
C.D (P=0.05)	0.03	0.15	0.29	0.15	7.94	8.59	0.46
Pre-sowing seed soaking							
Water Soaked	0.58	2.72	3.50	1.72	112.52	124.56	5.40
Soaked in 100ppm Na ₂ HPO ₄	0.61	2.88	3.70	1.74	117.48	130.42	5.75
Soaked in 100ppm KH ₂ PO ₄	0.62	2.90	3.72	1.77	118.43	133.21	5.83
S.Em (±)	0.01	0.03	0.06	0.03	1.71	1.85	0.10
C.D (P=0.05)	0.02	0.09	0.18	NS	4.86	5.26	0.28

Table 2. Effect of INM and pre-sowing seed soaking on dry matter accumulation (g m^{-2}) and crop growth rate ($\text{g m}^{-2}\text{day}^{-1}$) of *B. rapa*.

Fertility levels	Dry matter accumulation (g m^{-2})						Crop growth rate ($\text{g m}^{-2}\text{day}^{-1}$)							
	30	45	60	75	90	At harvest	30-45	45-60	60-75	75-90	DAS	DAS	DAS	DAS
Recommended dose	19.92	103.94	246.41	312.95	327.77	322.11	5.60	9.50	4.44	0.99				
100%RD+ Sulphur	23.09	108.40	254.92	327.38	342.33	337.67	5.69	9.77	4.83	1.00				
75%RD+ FYM	26.99	120.32	282.01	365.15	380.23	373.56	6.23	10.78	5.54	1.01				
75%RD+Vermicompost	29.62	135.30	299.26	386.17	402.10	397.76	7.04	10.93	5.79	1.07				
75%RD+ FYM +Azotobacter	32.71	141.46	316.85	418.83	434.73	430.73	7.25	11.70	6.80	1.07				
75%RD+ FYM +P.S.B	31.98	137.06	303.63	398.80	414.80	410.79	7.01	11.10	6.35	1.06				
75%RD+ FYM +Azotobacter+P.S.B	36.14	167.03	351.41	465.88	481.93	478.27	8.73	12.29	7.63	1.07				
75%RD+ FYM +Sulphur	29.04	128.91	286.31	373.35	388.17	384.34	6.66	10.50	5.80	0.99				
S.Em (+)	0.95	4.04	8.04	10.56	10.55	10.56	0.23	0.45	0.28	0.04				
C.D (P=0.05)	2.72	11.49	22.87	30.03	30.02	30.05	0.66	1.29	0.80	NS				
Pre-sowing seed soaking														
Water Soaked	27.24	124.28	275.19	363.73	379.22	374.22	6.44	10.06	5.90	1.04				
Soaked in 100ppm Na_2HPO_4	29.12	132.56	297.63	386.67	402.11	397.61	6.93	11.01	5.94	1.03				
Soaked in 100ppm KH_2PO_4	29.71	134.07	304.98	392.80	408.20	403.88	6.96	11.39	5.85	1.02				
S.Em (+)	0.58	2.47	4.93	6.46	6.46	6.47	0.14	0.28	0.18	0.06				
C.D (P=0.05)	1.66	7.03	14.01	18.39	18.39	18.41	0.41	0.79	NS	NS				

Table 3. Effect of INM and pre-sowing seed soaking on physiological activities and root growth of *B. rapa*.

Fertility levels	Stomatal conductance ($\text{m mol m}^{-2} \text{s}^{-1}$) at 45 DAS	Transpiration rate ($\text{m mol m}^{-2} \text{s}^{-1}$) at 45 DAS	NPR ($\text{m mol m}^{-2} \text{s}^{-1}$) at 45 DAS	Root dry weight (g plant^{-1})	Average root diameter of a plant (mm)	Average total root length of a plant (mm)
Recommended dose	264.33	2.96	37.34	1.148	0.642	1666.13
100%RD+ Sulphur	296.66	3.26	40.61	1.114	0.661	1662.93
75%RD+ FYM	390.29	3.49	43.33	1.230	0.716	1879.67
75%RD+Vermicompost	412.57	3.88	52.73	1.366	0.771	2010.60
75%RD+ FYM +Azotobacter	599.07	4.13	60.24	1.447	0.814	2019.30
75%RD+ FYM +P.S.B	572.88	3.97	53.92	1.543	0.878	2237.87
75%RD+FYM+Azotobacter+P.S.B	701.68	4.55	64.34	1.645	0.932	2403.17
75%RD+ FYM +Sulphur	338.97	3.43	44.13	1.288	0.717	1950.07
S.Em (+)	8.10	0.09	1.37	0.052	0.032	58.989
C.D (P=0.05)	23.05	0.25	3.90	0.148	0.091	167.90
Pre-sowing seed soaking						
Water Soaked	302.62	3.18	43.02	1.265	0.719	1858.63
Soaked in 100ppm Na_2HPO_4	386.04	3.70	50.86	1.367	0.780	1992.58
Soaked in 100ppm KH_2PO_4	652.51	4.25	54.86	1.411	0.800	2084.95
S.Em (+)	4.97	0.05	0.85	0.032	0.020	36.124
C.D (P=0.05)	14.11	0.15	2.39	0.09	0.056	102.82

resultant effect of balanced crop nutrition and high leaf area indices acted over the growth period. A strong and positive relationship between LAI and dry matter yield helped this fertility treatment to show highest values at all the growth stages. The crop growth rate gives an insight not only on the performance of a particular genotype, but also on the impact of the superimposed agronomic practices on the crop at any particular stage of growth as well as on the final yield. It was observed that the crop growth rate increased gradually up to 60 days after sowing then it declined sharply as the crop progressed towards its maturity during both the years. In all the stages the highest values of crop growth rate were recorded in treatments receiving 75% of recommended dose, farm yard manure, *Azotobacter* and P.S.B. As per the data recorded at different growth stages, it has also been found that there is no significant effect of fertility levels on crop growth rate after 75 days after sowing of yellow sarson crop. The crop growth rate also has a strong and positive relation with LAI and dry matter accumulation which influenced the results on these growth variables. The results revealed that the beneficial effect of organic manures and bio-fertilizers along with 25% curtailment in chemical fertilizer in improving the crop growth rate of yellow sarson at the *terai* region of eastern India. The results also showed significant effect of seed soaking with KH_2PO_4 and Na_2HPO_4 in comparison to seeds soaked with water. The highest values of dry matter accumulation at maturity (403.88 g m^{-2}) and of crop growth rate at 45-60 days after sowing ($11.39 \text{ g m}^{-2}\text{day}^{-1}$) were recorded with 100 ppm KH_2PO_4 soaked seed but no significant variation was found amongst the seed soaking treatments during 60-75 and 75-90 days after sowing.

Transpiration is necessary evil for any crop. It is a vital and unavoidable phenomenon of plant. As long as there is need of ingress and regress of carbon-dioxide, during metabolic process like photosynthesis and respiration, living cells have to be exposed, the transpiration will be unavoidable. Transpiration creates a suction force and helps in the ascent of sap, it affects the absorption of water and mineral by roots; it is supposed to play a necessary role in the translocation of food from one portion of the plant to the others, it brings about the opening and closing of stomata which indirectly influence the process of photosynthesis and respiration. 75% of recommended dose of chemical fertilizers along with farm yard manure, *Azotobacter* and P.S.B showed (Table 3) significantly higher stomatal conductance ($701.68 \text{ mmolm}^{-2}\text{s}^{-1}$) and transpiration rate ($4.55 \text{ mmolm}^{-2}\text{s}^{-1}$) over other nutrient management practices in yellow sarson at 45 days after sowing. As the net photosynthesis rate is the copulation of many of these physiological factors, same trend in result is obvious in net photosynthesis rate with same integrated nutrient management practice at the same stage of the crop ($64.34 \text{ mmolm}^{-2}\text{s}^{-1}$). Through better

root proliferation this nutrient management practice also showed significant increase in root dry weight plant^{-1} ($1.645 \text{ g plant}^{-1}$), average root diameter of a plant (0.932 mm) and total root length of a plant (2403.17 cm) over the 100% recommended dose of chemical fertilizers applied but these results are statistically at par with the results obtained in nutrient management practice consisting 75% recommended dose + farm yard manure+ P.S.B in yellow sarson plants. Pre-sowing seed soaking with KH_2PO_4 showed significantly higher stomatal conductance, transpiration rate as well as net photosynthesis rate of yellow sarson over the seed soaking treatment with Na_2HPO_4 and water. Significantly higher values of root dry weight plant^{-1} ($1.411 \text{ g plant}^{-1}$), average root diameter of a plant (0.800 mm) and total root length of a plant (2084.95 cm) were obtained with pre-sowing seed soaking with 100ppm KH_2PO_4 in comparison with water soaked seeds, but these results were statistically at par with 100ppm Na_2HPO_4 soaked seeds.

With the developed root system, higher uptake of nutrients reflected in to the seed yield of yellow sarson due to integrated nutrient management practice and soaking of seeds before sowing (Table 4). It was also revealed that the combination of inorganic sources and organic sources with or without bio-fertilizers are always beneficial for uptake of nutrients to the yellow sarson crop over the sole application of chemical fertilizers. A significant difference in nitrogen uptake has been observed with *Azotobacter* (75% of the recommended dose + farm yard manure + *Azotobacter* + P.S.B) and without *Azotobacter* (75% of the recommended dose + farm yard manure+ P.S.B) when the other components of the treatments remained the same. Significantly higher nitrogen, phosphate, potassium and sulphur uptake were observed where the crop received farm yard manure, *Azotobacter* and PSB along with inorganic fertilizer applied after 25% curtailment of recommended dose comparison to sole application of chemical fertilizers. Higher nutrient uptake by the yellow sarson crop in this integrated nutrient management practice was mainly due to better growth and higher dry matter yield of the crop apart from some contribution by increased nutrient content in the plant parts. Poor growth and low dry matter productivity were primarily responsible for the lowest nutrient uptake by the crop receiving only the chemical source of the nutrients. This might be explained as the inefficient utilization of nutrient by the crop in the absence of organic matter and bio-fertilizers particularly in the *terai* soil of West Bengal. This result indicated the need of an integration of different sources on plant nutrients for greater nutrient uptake by yellow sarson crop. Chand and Ram (2007) also observed the significant and positive correlation of coefficient between *Azotobacter* and nitrogen uptake in mustard when *Azotobacter* was applied with FYM. Improved growth of the crop together with high dry matter yield

Table 4. Effect of integrated nutrient management and seed-soaking agro-chemicals on uptake of nutrients and seed yield of *B. rapa*.

Fertility levels	Nitrogen (Kg ha ⁻¹)	Phosphorus (Kg ha ⁻¹)	Potassium (Kg ha ⁻¹)	Sulphur (Kg ha ⁻¹)	Seed yield (kg ha ⁻¹)	Stick yield (kg ha ⁻¹)	Harvest Index (%)
Recommended dose	115.05	36.56	104.33	26.12	982	2856	25.595
100%RD+ Sulphur	114.10	36.80	105.67	33.82	1012	2961	25.475
75%RD+ FYM	114.21	37.65	107.73	32.32	1148	3329	25.62
75%RD+Vermicompost	121.50	39.23	111.33	33.93	1195	3470	25.645
75%RD+ FYM + <i>Azotobacter</i>	132.53	39.33	114.54	36.09	1270	3651	25.83
75%RD+ FYM +P.S.B	126.87	41.98	115.00	38.52	1235	3499	25.995
75%RD+FYM+ <i>Azotobacter</i> +P.S.B	138.33	42.92	117.71	42.93	1374	3891	26.095
75%RD+ FYM +Sulphur	115.97	37.70	109.64	37.08	1152	3333	25.63
S.Em (±)	3.08	0.97	3.01	0.95	34.63	89.93	0.32
C.D (P=0.05)	8.76	2.76	8.55	2.71	97	253	NS
Pre-sowing seed soaking							
Water Soaked	116.87	37.34	106.63	33.16	1103	3178	25.725
Soaked in 100ppm Na ₂ HPO ₄	122.55	39.51	111.21	35.70	1194	3437	25.765
Soaked in 100ppm KH ₂ PO ₄	124.53	40.22	114.40	36.45	1216	3506	25.715
S.Em (±)	1.88	0.59	1.84	0.58	21	55	0.20
C.D (P=0.05)	5.36	1.69	5.24	1.66	60	155	NS

through extensive root system with better proliferation were mainly responsible for higher uptake of nutrients and better seed yield. Highest seed (1374 kg ha^{-1}) and stick yield (3891 kg ha^{-1}) were obtained with the application of 75% of the recommended dose of chemical fertilizers + farm yard manure + *Azotobacter* + PSB from the integrated nutrient management schedule. An increment of 39% in seed yield has been observed with this nutrient management practice over sole application of recommended dose of chemical fertilizers. Pre-sowing seed soaking also had a greater impact in uptake of nutrient and its conversion in to the biomass yield. Though pre-sowing seed soaking with 100ppm KH_2PO_4 showed highest seed (1216 kg ha^{-1}) and stick yield (3506 kg ha^{-1}), but these were statistically at par with 100ppm Na_2HPO_4 soaked seeds. Seeds soaked with water before sowing reflected 9% lesser seed yield compared to KH_2PO_4 soaked seeds. No significant variations were found in harvest index of yellow sarson with both integrated nutrient management practices and pre-sowing seed soaking treatments.

It is reported that that the important non-symbiotic nitrogen fixing bacteria *Azotobacter* and phosphate solubilizing bacteria can benefit rapeseed-mustard (Anonymous, 2005). *Azotobacter* and phosphate solubilizing bacteria (P.S.B) beside fixing ambient nitrogen to the soil and solubilize phosphates in the soil, can benefit rapeseed-mustard by producing growth hormones, *viz.*, IAA, gibberellins and making the soil nutrient in available form (Bais *et al.*, 2006 and Bisht *et al.*, 2009). These hormones might have played a vital role to stimulate root growth and development as well as better utilization of light interception which helped in greater uptake of nutrients by efficient photosynthetic activities. The maximum root length at harvest in rapeseed was also observed by Mitra *et al.* (2008) with the fertility levels in which both organic and inorganic sources were applied. Side by side farm yard manure is considered as a good substrate for the bio-fertilizers. With a buffering tendency, farm yard manure also increases fertilizer use efficiency, supplies micronutrients and makes the nutrients in the soil more available to plants even in slightly acidic soil. Thus combined application of 75% recommended dose, farm yard manure, *Azotobacter* and P.S.B might helped the plants in absorption of nutrients from soil solution by expanding the energy in available form which ultimately helped the plant to develop a good crop canopy with good number of primary branches, root system and leaf size. These factors ultimately triggered the seed yield of yellow sarson crop. Chatterjee (2013) also found the beneficial effects of farm yard manure, *Azotobacter* and phosphate solubilizing bacteria on tomato physiological traits at foot-hills of eastern Himalaya. Considering other factor, better preservation of cellular substances with sequential changes in the viscosity and elasticity of

protoplasm, lower water deficit, increase in water balance and extensive root system of plants are the physiological basis for pre-sowing seed soaking (Bharathi *et al.*, 2004). Water absorption of seeds by greater membrane permeability and translocation of sugars from seed to young growing points is the another advantage of pre-sowing seed soaking (Balasubramaniyan and Palaniappan, 2002). Thus pre-sowing seed soaking has a greater role in early emergence of seedlings with proper root and shoot growth, which helps a plant in uptake of nutrients accumulated at the root zone at different growth stages. High seedling vigour, faster emergence and increased DNA at the growing points might be helpful for the plants towards uptake and higher translocation of the nutrients efficiently. Enhanced physiological processes from very beginning of the growth stages recorded increased plant height thereby. ATP is the biological energy needed for every biosynthetic pathways as well as biological work. During early crop establishment, the embryo of a seed not only acts as the source for enzyme substrate but also co-factors for the synthesis of ATP. So the pre-sowing seed soaking with phosphorus containing salts might have a contribution in early active absorption, translocation of plant nutrients accumulated in available form at the soil solution near the root zone of the plants and better photosynthetic activities with light interception. Absorption of nutrients from soil solution containing low concentration of nutrients compared to plant sap by expanding energy which largely depends on growth and development of roots which determines the leaf size, number of leaves and leaf area index. Pre-sowing seed soaking with chemicals has a role in early emergence, vigorous seedlings along with steady root growth. Seeds soaked with KH_2PO_4 and Na_2HPO_4 might have a great influence on better uptake and translocation of the plant nutrients and ultimately increased seed yield of yellow sarson. This was in conformity with the results found by Paul *et al.* (1999). Similar results were also found by Mondal *et al.* (2004) in a field study to evaluate the effect of pre-sowing seed treatment with water and different agro-chemicals in *B. juncea*. One-fourth curtailment in the recommended dose of chemical fertilizers and inclusion of organics and bio-fertilizers was proved to be superior over the use of only chemicals in terms of growth, nutrient uptake and productivity of yellow sarson. One another remarkable factor needed to be addressed that the use of agro-chemicals for soaking of seeds before sowing which also ultimately gave yellow sarson a uniform stand and productivity.

Conclusion

Integrated nutrient management and pre-sowing seed soaking of yellow sarson showed distinct effect on yellow sarson growth attributes, nutrient uptake and seed yield, a recommendation may come out in

combination of both the factors. In this study, 75% recommended dose of chemical fertilizer, farm yard manure, *Azotobacter*, phosphate solubilizing bacteria and sowing of seeds after soaking of seeds in 100ppm KH_2PO_4 came out as the best treatment among the treatment combinations used. This package can be beneficial for the rapeseed mustard growers at the eastern part of Indian Sub-Himalayan *terai* plains.

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