Seed Yield Variation of Rapeseed (*Brassica campestris*) by Integrated Nutrient Management Practices under Rain-fed Condition of Terai Region in West Bengal, India

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Abstract

A field experiment was conducted during the winter seasons of 2007-08 and 2008-09 to study the physiological analysis of seed yield variation of rapeseed (*Brassica campestris*) as influenced by integrated nutrient management practices. Amongst the different sources of organics (FYM @ 10 t ha^{-1} and vermicompost, neem cake and poultry manure each @ 5.0 t ha^{-1}), vermicompost @ 5.0 t ha^{-1} significantly influenced the leaf area index (LAI), dry matter accumulation (DMA), crop growth rate (CGR), net assimilation rate (NAR), yield attributes and yield over other organics. The combined application of organics (FYM @ 2.5 t ha^{-1}, vermicompost, neem cake and poultry manure each @ 1.25 t ha^{-1}) along with 50% recommended dose of fertilizer (60:30:30 kg ha^{-1} of $N:P_2O_5:K_2O$, respectively) significantly influenced the LAI, DMA, CGR, NAR, yield attributes and yield.

1. Introduction

The productivity of a crop is mainly dependent on its potential for photosynthesis and photosynthetic area developed. Low organic matter content in entisols coupled with low and imbalanced application of macro and micro-nutrients to the crop limits the full potential of yield and is the main yield barrier for crops (Ghosh et al., 2003). Integrating chemical fertilizers with organic manures was quite promising, not only in maintaining higher productivity but also in providing greater stability in crop production (Nambiar and Abrol, 1992). Limited availability of farm yard manure (FYM) is however an important constraint in its use as a source of nutrient. Poultry manure is now available in abundance due to development of poultry industry. Vermicompost is gaining popularity and can be produced at farmer's level. Neem cake is also known to serve as a source of organic manures. Now, the determination of crop growth rate and net assimilation rate have special significance as these parameters provide distinct information about some of the physiological functions like rate of dry matter accumulation, net photosynthetic area (Hunt, 1978). Therefore the present investigation was undertaken to study the analysis of growth and productivity of rapeseed (*Brassica campestris* L. var. yellow sarson) as influenced by integrated nutrient management practices under rain-fed conditions.

2. Materials and Methods

The experiment was carried out at Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during 2007-08 and 2008-09. The farm is situated at 26°19'86'' N latitude and 89°23'53'' E longitude and at an altitude of 43 masl. The soil is sandy loam (62-65% sand, 18% silt, 16-17% clay), acidic with a pH of 5.85, 0.52% organic carbon, low in available nitrogen (217.65 kg ha^{-1}), medium in available phosphorus (22.82 kg ha^{-1}), and available potash (174.68 kg ha^{-1}). The experiment was conducted during the *rabi* seasons where the climate of *terai* zone is sub-tropical in nature with distinctive characteristics of high rainfall, high humidity and a prolonged winter. Very low rainfall, cool temperature and dry clear sunny days, with occasional heavy rainfall and high humidity are the characteristics of winter season. The winter, in most of the years falls in late February and is extended even upto March. Twelve treatments, viz. T_1=100% recommended dose of fertilizer (RDF) (60:30:30 kg ha^{-1} of $N:P_2O_5:K_2O$); T_2=100% RDF+Borax @ 10.0 Kg ha^{-1}; T_3=FYM @ 10.0 t ha^{-1}; T_4=Vermicompost (VC) @ 5.0 t ha^{-1}; T_5=Neem cake (NC) @ 5.0 t ha^{-1}; T_6=Poultry manure (PM) @ 5.0 t ha^{-1};

T_7=100% RDF+FYM @ 5.0 t ha^{-1}; T_8=100% RDF+VC @ 2.5 t ha^{-1}; T_9=100% RDF+Neemcake @ 2.5 t ha^{-1}; T_{10}=100% RDF + Poultry manure @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control laid out in RBD design with three replications. Rapeseed variety Jhumka (NC-1) was sown in mid-November during both the years of experimentation with the spacing of 30x10 cm^2. Fertilizers were applied in the form of urea, single super phosphate and murate of potash, respectively. Half of the nitrogenous fertilizer and entire dose of P_2O_5 and K_2O along with treatment-wise organic manures were applied at the time of final land preparation and rest half of nitrogen was applied at 20 days after sowing (DAS). Crop growth rate (CGR) was calculated according to the following formula and expressed in g m^{-2} day^{-1} (Watson, 1952).

$$CGR = \frac{W_2\text{-}W_2}{t_2\text{-}\ t_1}$$

Where, W_1 and W_2 are the total dry weight of the plants gained at times t_1 and t_2, respectively.

Net assimilation rate was calculated by the formula as described by Watson (1958) and was expressed in g m^{-2} day^{-1}.

$$NAR = \frac{W_2\text{-}W_2}{L_2\text{-}\ L_1} \times \frac{Log_eL_2\text{-}Log_eL_2}{t_2\text{-}\ t_1} = \frac{CGR}{\text{Mean LAI}}$$

Where, W_1 and W_2 are the dry weight of plants at times t_1 and t_2, respectively and L_1 and L_2 are corresponding leaf area indices. The mean leaf area index (LAI) was calculated as per the formula given below

$$\text{Mean LAI (L)} = \frac{L_2\text{-}\ L_1}{Log_eL_2\text{-}Log_eL_1}$$

Where, L_1 and L_2 are the leaf area indices at two successive occasions. Leaf area duration (LAD) was calculated by the formula (Watson, 1952): LAD (day)=Mean LAI×duration (d). LAD was calculated in different growth stages of maize starting from 30 to 90 DAS. Leaf area was measured with leaf area meter measuring instrument.

The data collected from the field and laboratory experiments were subjected to statistical analysis appropriate to the design and the treatment variations were tested for significance by F test (Gomez and Gomez, 1983). The standard errors of mean and critical differences are indicated in tables. For determination of critical differences at 5% level of significance, Fisher and Yates (1963) tables were consulted.

3. Results and Discussion

3.1. *Leaf area index (LAI)*

Irrespective of treatments, LAI increased with the advancement of crop age and it reached its peak at 60 DAS (Figure 1). LAI varied under different conditions of growth with different nutrient management options. Among the organics, treatment receiving VC @ 5.0 t ha^{-1} (T_4) have highest LAI (4.11 and 4.08) which was statistically at par with NC @ 5.0 t ha^{-1} (T_5) during both the years of experimentation. This was due to the emergence and enlargement of new branches and leaves during rosette stage that not only stopped at the peak flowering stage, but also decreased gradually with the senescence of leaves. Treatment receiving 50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1} (T_{11}) recorded highest value of LAI (4.72 and 4.68) at 60 DAS which was statistically at par with T_9, T_8 and T_{10} during both the years of experimentation. This might be due to accumulation of soluble nitrogen, sugar, starch, proline and increased internal CO_2 concentration and net photosynthesis from the combined application of organic and inorganic sources of nutrient. Sharma et al. (2007) also found similar result.

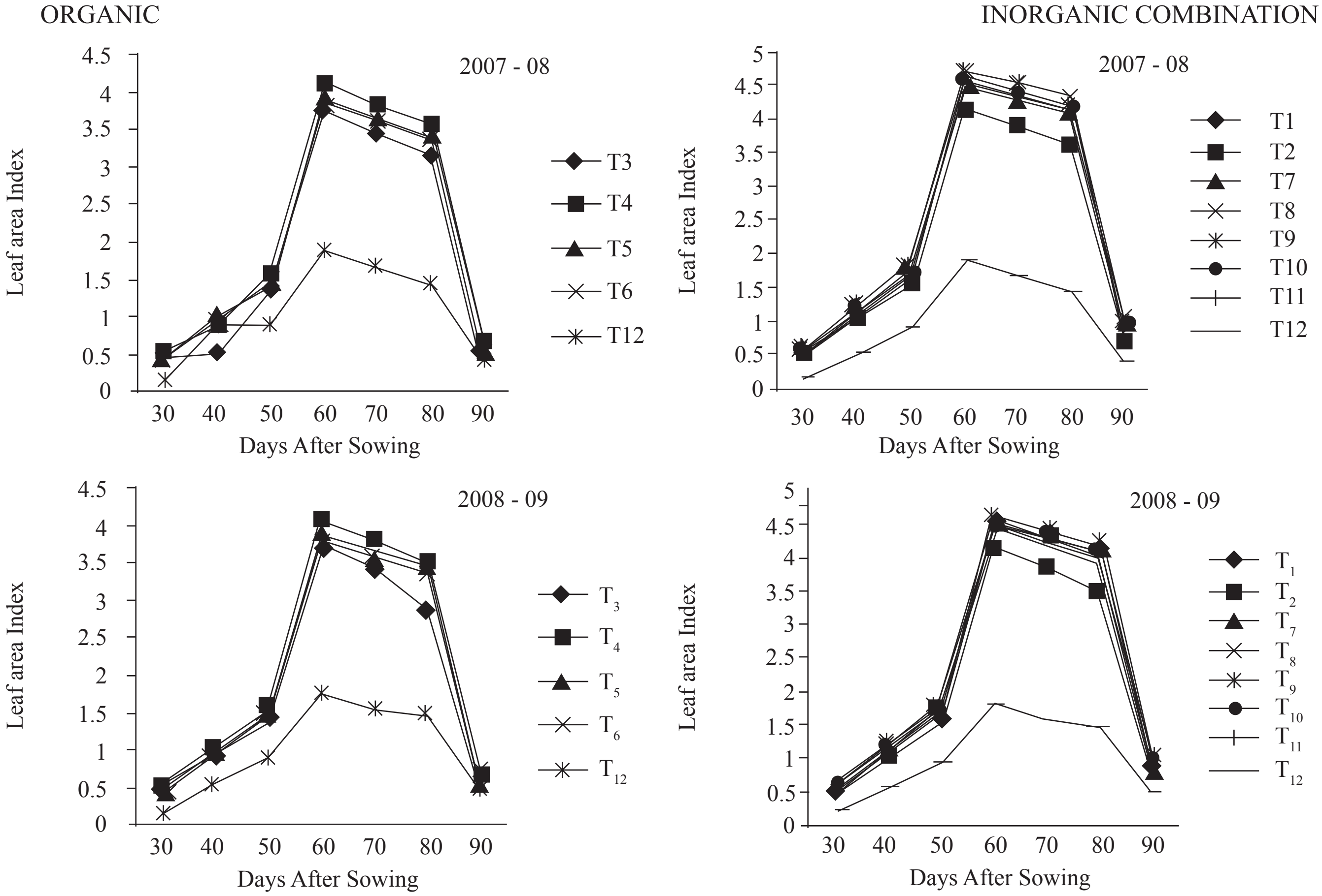
3.2. *Leaf area duration (LAD)*

The leaf area duration was significantly the highest with the application of 50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1} (T_{11}) at 50-60 DAS, in 2007-08 and 2008-09, respectively (Table 1).

Similarly, at the peak LAD, these three treatment combinations, i.e. RDF with FYM @ 5.0 t ha^{-1} (T_7), T_{11} and T_8 were statistically at par with higher LAD values compared to other treatments and unfertilized control (T_{12}). The reflection of higher LAD lies in the greater interception of solar radiation over longer periods of time, which in turn, generally means larger duration of photosynthesis and consequently, greater total dry matter buildup and grain yield. The results obtained were corroborative with the findings of Kumar and Gangwar (1972) and Gill and Narang (1993).

3.3. *Dry matter accumulation (DMA)*

Dry matter accumulation increased sharply and reached near maximum at 75 DAS, after which it increased very slowly and remained more or less constant (Figure 2). Among the organics treatment receiving VC @ 5.0 t ha^{-1} (T_4) have highest accumulated dry matter (294.62 and 294.37 g m^{-2}), which was statistically at par with NC @ 5.0 t ha^{-1} (T_5) during both the years of experiment. This was probably due to the encouraging effects of VC with balanced application of N, P and K ensuring the enhanced growth and metabolic activities of the crop (Figure 2). Treatment receiving 50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1} (T_{11}) recorded the highest (557.81 g m^{-2}) dry matter accumulation followed by T_9 (100% RDF+NC @ 2.5 t ha^{-1}) and T_8 (100% RDF+VC @ 2.5 t ha^{-1}) which recorded significantly better results compared to control and other treatments, in 2007-08. The results corroborated with the findings of Khanpara et al. (1993a) and Tomar et al. (1996).



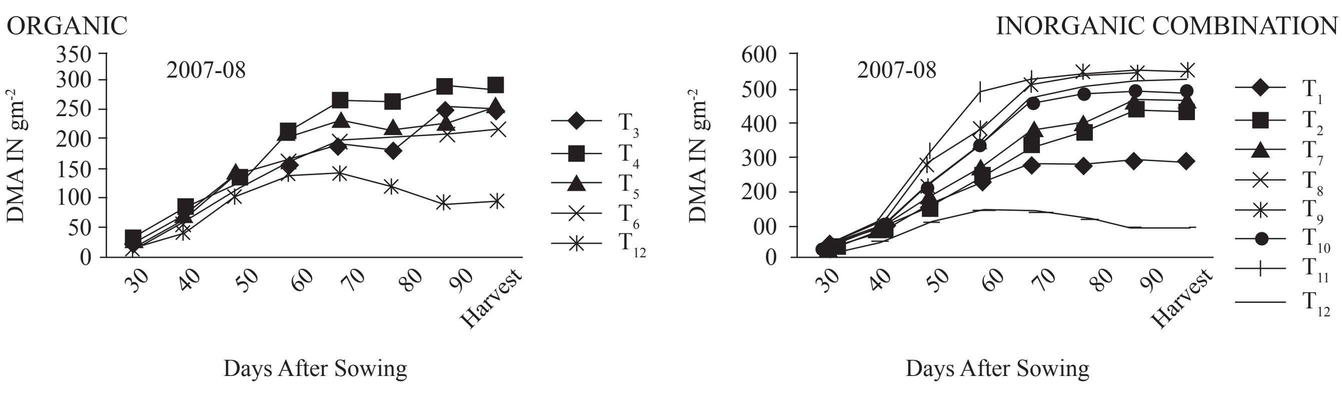
T_1=100% RDF (60:30:30 kg ha^{-1} of N:P_2O_5:K_2O); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control

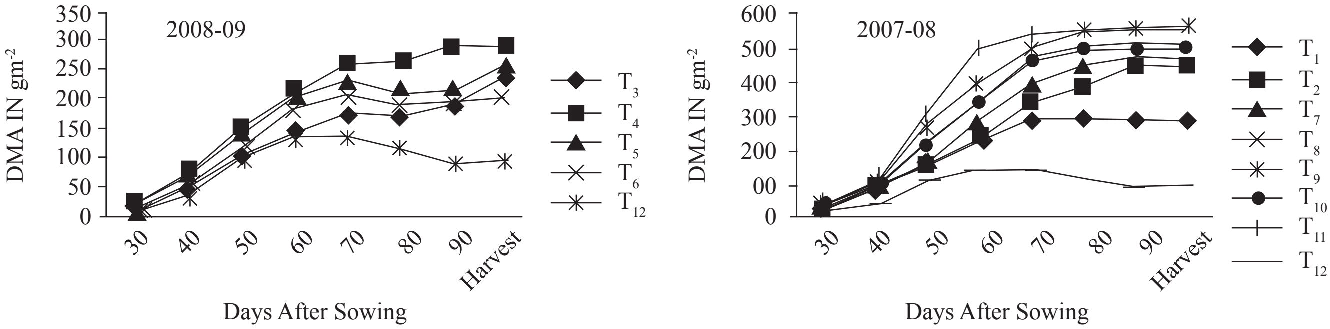
Figure 1: Effect of integrated nutrient management on leaf area index (LAI) of rapeseed at different stages of crop growth

3.4. Crop growth rate (CGR)

CGR increased considerably upto 60-70 DAS coinciding with the period of increasing LAI, and then decreased later in all the treatments due to natural senescence of lower leaves. It is clearly observed from the treatment receiving VC @ 5.0 t ha^{-1} (T_4) recorded highest CGR (9.73 and 9.83 g m^{-2} day^{-1}) at 60-70 DAS which was statistically at par with NC @ 5.0 t ha^{-1} (T_5) within the organics during both the years of experiment (Table 2).

The onset of the reproductive phase of the crop coincided with the period between 45-50 DAS and CGR was maximum in this period where there was fullest manifestation of all the vegetative parts. At 60-70 DAS period maximum growth rates were recorded (12.61 and 12.36 g m^{-2} day^{-1}) and it was comparatively higher in treatment receiving 50% RDF+FYM @ 2.5 t ha^{-1}+VC @1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25





T_1=100% RDF (60:30:30 kg ha^{-1} of $N:P_2O_5:K_2O$); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control

Figure 2: Effect of integrated nutrient management on dry matter accumulation (DMA) of rapeseed at different stages of crop growth

Table 1: Effect of integrated nutrient management on leaf area duration of rapeseed at different stages of crop growth

Treatments	Leaf area duration (day)											
	30-40 DAS		40-50 DAS		50-60 DAS		60-70 DAS		70-80 DAS		80-90 DAS	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1	17.10	17.17	29.65	29.60	61.40	60.50	95.05	91.80	89.03	84.87	41.23	40.47
T_2	17.41	17.67	30.24	30.87	62.26	61.73	96.42	92.37	90.59	85.23	42.85	41.27
T_3	15.58	15.17	27.11	26.87	55.39	55.10	92.72	82.93	85.66	73.20	32.85	31.73
T_4	17.01	16.73	29.64	29.17	60.35	60.17	94.02	91.07	87.92	84.37	39.60	39.27
T_5	16.26	16.13	28.30	28.20	58.13	57.80	93.61	86.23	88.39	81.27	37.77	37.63
T_6	15.63	15.53	27.77	27.57	57.18	56.67	82.93	85.53	77.83	80.53	37.06	36.80
T_7	18.32	18.03	32.10	31.73	66.23	65.83	115.51	100.23	111.02	94.13	49.81	47.90
T_8	18.71	18.77	33.01	33.20	68.51	67.60	110.53	102.33	106.00	97.37	50.75	52.00
T_9	19.34	19.27	34.07	33.90	68.91	68.57	103.91	103.30	99.61	99.33	52.05	54.40
T_{10}	18.55	18.60	32.73	32.97	68.28	67.10	109.36	100.73	104.67	95.03	50.44	48.73
T_{11}	20.02	19.67	34.73	34.60	70.15	69.87	112.93	105.27	108.93	100.37	54.78	55.83
T_{12}	7.29	7.80	16.22	16.43	32.86	29.93	40.59	38.60	35.56	35.03	18.90	20.17
SEm±	0.42	0.29	0.62	0.45	0.65	0.51	6.81	0.52	6.48	0.74	0.69	0.58
CD (p=0.05)	0.88	0.59	1.28	0.92	1.34	1.07	14.12	1.07	13.44	1.54	1.44	1.21

T_1=100% RDF (60:30:30 kg ha^{-1} of $N:P_2O_5:K_2O$); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control; Y_1=2007-08; Y_2=2008-09; DAS=Days after sowing

t ha^{-1} (T_{11}) followed by full RDF with NC @ 2.5 t ha^{-1} (T_9) and full RDF with VC @ 2.5 t ha^{-1} (T_8) during both the years of experimentation. This was due to greater accessibility of applied nutrients and higher uptake of primary nutrients by rapeseed from the combined application of organic and inorganic sources of nutrients. These results are in agreement with Sharma et al. (2007) and Kumar and Yadav (2007).

3.5. *Net assimilation rate (NAR)*

Observation on net assimilation rate at different stages of crop growth revealed that irrespective of INM treatments and year of experimentation, NAR kept on increasing successively in successive observations till the period of 40-50 days after sowing when it reached at its maximum and thereafter it declined successively in successive observations recorded till 80-90 days after-sowing (Table 3).

When the crop was in the ripening phase, NAR showed a decreasing trend. Similarly significantly higher NAR was recorded in T_{11} (50% RDF+FYM @ 2.5 t ha^{-1}+VC @1.25

Table 2: Effect of integrated nutrient management on crop growth rate of rapeseed at different stages of crop growth

Treatments	Crop Growth Rate (g m^{-2} day^{-1})											
	30-40 DAS		40-50 DAS		50-60 DAS		60-70 DAS		70-80 DAS		80-90 DAS	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1	6.01	5.95	7.11	7.09	9.57	9.24	9.81	9.94	4.78	4.61	1.42	1.42
T_2	6.14	6.14	7.50	7.30	9.63	9.44	9.97	10.07	4.80	4.60	1.32	1.32
T_3	3.96	4.01	5.12	5.17	7.68	6.26	7.75	6.52	4.21	3.27	1.87	1.87
T_4	5.99	5.72	4.14	7.01	9.48	9.08	9.73	9.83	4.63	5.37	2.11	2.28
T_5	5.37	5.35	6.96	6.96	9.42	9.03	9.69	9.75	4.52	4.55	2.05	2.22
T_6	3.84	4.19	5.39	6.57	7.89	8.76	7.96	9.59	4.39	4.23	2.01	2.15
T_7	6.11	6.12	9.81	7.95	10.83	11.25	11.43	11.10	2.73	5.80	2.04	1.60
T_8	6.73	6.75	11.72	12.10	12.90	12.92	13.21	12.67	3.51	3.33	1.53	0.52
T_9	6.84	6.89	18.51	17.12	16.65	16.98	14.87	14.30	2.95	3.72	1.15	0.81
T_{10}	6.43	6.47	12.09	12.28	12.29	12.09	12.61	12.36	2.84	2.69	0.68	0.57
T_{11}	6.92	6.77	20.95	19.59	18.23	18.99	15.12	16.11	1.78	1.34	0.77	0.66
T_{12}	3.12	2.89	5.16	5.02	6.32	6.11	6.45	6.35	3.82	3.61	0.70	0.72
SEm±	0.16	0.15	0.22	0.21	0.25	0.26	0.10	0.10	0.18	0.17	0.14	0.13
CD (p=0.05)	0.33	0.33	0.46	0.44	0.56	0.54	0.20	0.22	0.34	0.36	0.30	0.30

T_1=100% RDF (60:30:30 kg ha^{-1} of N:P_2O_5:K_2O); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control; Y_1=2007-08; Y_2=2008-09; DAS=Days after sowing

Table 3: Effect of integrated nutrient management on net assimilation rate of rapeseed at different stages of crop growth

Treatments	Net assimilation rate (g m^{-2} day^{-1})											
	30-40 DAS		40-50 DAS		50-60 DAS		60-70 DAS		70-80 DAS		80-90 DAS	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1	3.52	3.47	2.40	2.40	1.56	1.53	1.03	1.08	0.54	0.54	0.34	0.35
T_2	3.53	3.48	2.48	2.37	1.55	1.53	1.04	1.09	0.53	0.54	0.31	0.32
T_3	2.54	2.65	1.89	1.93	1.39	1.14	0.85	0.79	0.50	0.45	2.37	0.59
T_4	3.52	3.42	1.40	2.41	1.57	1.51	1.04	1.08	0.53	0.64	0.53	0.58
T_5	3.31	3.31	2.46	2.47	1.62	1.56	1.04	1.13	0.51	0.56	0.54	0.59
T_6	2.46	2.70	1.94	2.38	1.38	1.55	0.96	1.12	0.57	0.53	0.54	0.58
T_7	3.34	3.39	3.06	2.50	1.64	1.71	1.01	1.11	0.25	0.62	0.41	0.33
T_8	3.60	3.59	3.55	3.65	1.88	1.91	1.21	1.24	0.33	0.34	0.30	0.10
T_9	3.54	3.58	5.43	5.05	2.42	2.48	1.43	1.38	0.30	0.37	0.22	0.15
T_{10}	3.47	3.48	3.70	3.72	1.80	1.80	1.16	1.23	0.27	0.28	0.14	0.12
T_{11}	3.46	3.44	6.03	5.66	2.60	2.72	1.35	1.53	0.17	0.13	0.14	0.12
T_{12}	4.43	3.78	3.22	3.08	1.93	2.05	1.59	1.65	1.08	1.03	0.37	0.36
SEm±	0.26	0.18	0.15	0.12	0.05	0.05	0.07	0.01	0.04	0.03	0.05	0.03
CD (p=0.05)	0.53	0.38	0.30	0.25	0.10	0.10	0.15	0.03	0.08	0.05	0.11	0.07

T_1=100% RDF (60:30:30 kg ha^{-1} of N:P_2O_5:K_2O); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control; Y_1=2007-08; Y_2=2008-09; DAS=Days after sowing t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}) followed by T_9 (100% RDF+NC @ 2.5 t ha^{-1}) during both the years of experimentation. The reproductive phase of the crop roughly coincided with 40-50 DAS where NAR was maximum due to fullest manifestations of all the vegetative parts which leads to higher photosynthate production efficiency and might be the resultant effect of higher CO_2 assimilation and greater transpiration particularly at the optimum soil moisture regime at the critical stages of crop growth (Sharma and Singh, 1994; Baig et al., 1995).

3.6. *Seed yield*

The seed yield of rapeseed was significantly influenced by different INM treatments during both the years. Among the organics, VC @ 5.0 t ha^{-1} (T_4) recorded highest seed yield (10.24 and 10.14 q ha^{-1}) which was statistically at par with NC @ 5.0 t ha^{-1} (T_5) during both the years (Table 4) due to higher dry matter accumulation which leads to higher CGR and NAR. The highest seed yield of 13.61 and 13.34 q ha^{-1} was recorded under T_{11} (50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}) followed by T_9 (100% RDF+NC @ 2.5 t ha^{-1}) and T_8 (100% RDF+VC @ 2.5 t ha^{-1}).

Table 4: Effect of integrated nutrient management on see yield of rapeseed

Treatments	Seed yield (q ha^{-1})		
	30-40 DAS		40-50 DAS
	Y_1	Y_2	Y_1
T_1	12.42	12.51	12.47
T_2	12.61	12.69	12.65
T_3	8.08	7.86	7.97
T_4	10.24	10.14	10.19
T_5	9.26	9.06	9.16
T_6	8.57	8.29	8.43
T_7	12.89	12.94	12.92
T_8	13.25	13.21	13.23
T_9	13.48	13.32	13.40
T_{10}	13.04	13.13	13.09
T_{11}	13.61	13.34	13.48
T_{12}	7.67	7.49	7.58
SEm±	0.18	0.18	0.10
CD (p=0.05)	0.38	0.38	0.22

T_1=100% RDF (60:30:30 kg ha^{-1} of N:P_2O_5:K_2O); T_2=100% RDF+Borax @ 10 kg ha^{-1}; T_3=FYM @ 10 t ha^{-1}; T_4=VC @ 5 t ha^{-1}; T_5=NC @ 5.0 t ha^{-1}; T_6=PM @ 5.0 t ha^{-1}; T_7=T_1+FYM @ 5 t ha^{-1}; T_8=T_1+VC @ 2.5 t ha^{-1}; T_9=T_1+NC @ 2.5 t ha^{-1}; T_{10}=T_1+PM @ 2.5 t ha^{-1}; T_{11}=50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}; T_{12}=Control; Y_1=2007-08; Y_2=2008-09; DAS=Days after sowing

In the pooled data, T_{11} (50% RDF+FYM @ 2.5 t ha^{-1}+VC @ 1.25 t ha^{-1}+NC @ 1.25 t ha^{-1}+PM @ 1.25 t ha^{-1}), T_9 (100% of RDF+NC @ 2.5 t ha^{-1}) and T_8 (100% RDF+VC @ 2.5 t ha^{-1}) showed 77.8, 76.7 and 74.5% increase in yield over absolute control (T_{12}), respectively. These results confirm the findings of Abrol et al. (2007) and Subhash and Ram (2007). It was indicative of the fact that farm yard manure, vermicompost, poultry manure and neem cake in combination with chemical fertilizer, i.e. with nitrogen, phosphorus, potassium exhibited their role in various physiological functions, movement of growth regulators within the plant, germination and growth of pollen grains and pollen tubes in turn promoting higher yield and yield attributes which ultimately shows that different growth factors directly or indirectly affects the rapeseed yield.

4. Conclusion

From the foregoing discussion, it can be concluded that among all treatments under test, T_{11} (1.25 t ha^{-1} VC, 1.25 t ha^{-1} NC, and 1.25 t ha^{-1} PM with 2.5 t ha^{-1} FYM with 50% RDF) or T_9 [2.5 t ha^{-1} NC with 100% RDF (N:P:K=60:30:30 kg ha^{-1})] may be advocated to meet the demand of multiple nutrients and to sustain the higher productivity of rapeseed in the foothills of eastern India.

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