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Growth Response of Wheat as Affected by Different Nutrient Sources and NPK Levels under Vertisols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Growth analysis such as crop growth rate (CGR), relative growth rate (RGR), leaf area index (LAI) and net assimilation rate (NAR) are the most important traits in prediction of yield. Keeping in this view a field experiment was conducted to estimate growth response of wheat as affected by different nutrient sources and NPK levels under Vertisols in split plot design with 3 replications at the experimental field of JNKVV, Jabalpur during winter (*Rabi*) 2019. The treatment comprised of 3 sources of nutrient M_1- Inorganic sources (NPK fertilizers), M_2- organic sources (FYM, vermicompost, biofertilizers *Azotobacter* and PSB) and M_3- Integrated sources (50% Inorganic + 50% organic) as main treatments and 5 NPK levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value (STV) for target yield of 6 t ha^{-1} as sub treatments were replicated thrice. The results showed that among the different sources of nutrients, maximum growth responses was found with inorganic sources of nutrient, which was significant over organic sources of nutrient followed by integrated sources of nutrient. All the growth characters (LAI, NAR,

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RGR and NAR) were higher at high fertility (200% RDF) which was found significant over 100% RDF and STV based value and at par with 150% RDF. Thus, from the present investigation concluded that the adequate supply of plant nutrient in inorganic sources with 150% RDF levels helps in better growth of wheat which ultimately helps in higher yield.

Keywords: Leaf area index; net assimilation rate; relative growth rate.

1. INTRODUCTION

Progressive growth in the human population is a fact, and it will reach at least nine billion by 2050 [1]. The food gap can be covered by several actions, but the most important and effective are both the increase in yields of crops, and area of arable soils [2]. In the past, the first factor was responsible for 55%-60% increase in the food production [3]. Wheat *(Triticum aestivum L.)* is the most important cereal crop in world and is the staple food for humans [2]. Wheat is one of the most important crops in the world that can cover the food gap [4]. The yielding potential of this crop is high. But the world average yield of wheat is drastically lower and amounts to only 3.2 t ha^{-1}. Nutrient management has played an important role in increasing the productivity of this crop. Fertilizers have an axial role in enhancing the growth and production in developing countries especially after the introduction of high yielding and fertilizer responsive crop cultivars [5]. In commercial production, quantity's of NPK fertilizers is very important factor affecting plant growth and production, especially the balance among N, P and K in soil [6]. Application of optimum dose of nutrients with appropriate method is considered as a key to success in increasing yield of any crop [7]. Therefore, application of fertilizers might be a successful tool for improving the agrochemical conditions of the soil. It could induce simulative effect on plant growth and productivity, especially with applying chemical fertilizer [6]. The 'Green Revolution' in India has increased the yields tremendously, however, it served as a mixed blessing, as on one hand ambitious use of agrochemicals boosted the food grain production and on the other hand, it destroyed the agricultural ecosystem [8]. The farmers use chemical fertilizers to increase crop production as they are more economical, affordable, easy to use and quick in response [9]. No doubt, the use of chemical fertilizers is the quickest way of boosting crop production, but their increasing prices, soil health deterioration, sustainability and pollution considerations in general have led to renewed interest in the use of organic manures [8]. Use of organics alone does not result in spectacular increase in crop yields due to their low nutrient status but the supplementary and complementary use of such sources is known to enhance the utilization efficiency of fertilizers [10]. So, there is a need to draw a mid-way between organic and inorganic extremities that may sustain crop yields without deteriorating soil fertility and/or productivity [9].This can only be maintained at sustainable level by nutrients via integrated approach [11]. Combined application of organic and inorganic nutrient sources improved synergism and synchronization between nutrient release and plant recovery thus resulted in better crop growth and yield [12]. Growth is a vital function of plants and is an indication of a gradual increase in number and size of cells [13]. Growth analysis such as crop growth rate, relative growth rate and leaf area index are the most important traits in prediction of yield [14]. Growth analysis is a suitable method for plant response to different environmental conditions during plant life also observed significant positive interaction between fertilizer treatments and physiological stages of wheat growth [15, 16]. The allocation and partition of photosynthates in plants can be better understood by using by using the technique of growth analysis of plants throughout their entire cycle or even part of it. Growth analysis is a laborious technique, but relatively simple and easy to perform using a few pieces of equipment. It basically consists of determining the leaf area of plants and the dry mass of each organ of the entire plant, normally every week [17]. With the obtention of the leaf area and the dry mass of the different plant organs, the instantaneous or average physiological indicators of growth such as crop growth rate, relative growth rate, net assimilation rate, specific leaf area, leaf area ratio and leaf area duration can be determined [18]. Many researchers reported that the use of balanced fertilizers have a promising role in growth and development of crop plants which resulted in improved quality and quantity of the agricultural produce [15]. Therefore, this study was conducted to identify the most effective source of nutrient and NPK levels for wheat to enhance physiological growth and ultimately higher productivity.

2. MATERIALS AND METHODS

2.1 Experiment Details

A field experiment was carried out in the research field of Department of Soil Science and Agricultural Chemistry Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during the 2018-2019. The soil of the experimental site was Typic Haplustert, clay in texture neutral in reaction, non calcareous, medium in organic carbon content, medium in available nitrogen, phosphorus, and potassium and low in DTPA extractable Zn. The treatment comprised of 3 sources of nutrient M_1- chemical, M_2- organic and M_3- integrated (chemical and organic) as main treatments and 5 fertility levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value for target yield of 6t ha^{-1} as sub treatments were replicated thrice in a split plot design. The wheat crop (GW-366) sown on with spacing of 22.5 cm row to row. The observations were recorded from each plot at 21, 45, 65 and 90 DAS of wheat.

2.2 Growth Analysis

For computing LAI, leaves from 5 plants were collected and cleaned with water and then wiped with tissue paper. Using a leaf area meter (Model LICOR 3000, USA), the area of fresh green leaves was measured and expressed in cm^2/plant. While placing the leaf on the roller utmost care was taken to avoid overlapping of the leaf. Plants from one-meter row length were cut near the ground surface for dry-matter estimation from each treatment, at 21, 45, 60 and 90 DAS. The whole plants along with leaf in 1 m^2 area were collected and shade dried for 7 days and then oven dried at 65±5°C for one week. The dry weight was recorded with the help of electronic balance and expressed in g/m^2. The recorded dry weight data at 21, 45, 60 and 90 DAS was used to calculate the mean leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR). The mean LAI, CGR, RGR and NAR worked out with the following formulas:

1. Leaf area index (LAI)

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

2. Crop growth rate (CGR) g m^2 day

$$\text{CGR} = \frac{W2-W1}{P\,(t2-t1}$$

Where, P = Ground area, W_1 = Dry weight of $plant^{-1}$ m^2 recorded at time t_1, W_2 = Dry weight of $plant^{-1}$ m^2 recorded at time t_2, t_1 and t_2 were the interval of time, respectively and it is expressed in g m^2 day

3. Relative growth rate (RGR) (g^{-1} g^{-1} day)

$$\text{RGR} = \frac{(\text{In W2 - In W1})}{(t2 - t1)}$$

Where, In = Natural log, W_1 = Dry weight of $plant^{-1}$ m^2 recorded at time t_1, W_2 = Dry weight of $plant^{-1}$ m^2 recorded at time t_2, t_1 and t_2 were the interval of time, respectively and is expressed as g^{-1} g^{-1} day

4. Net Assimilation Rate (NAR) (g m^{-2} day^{-1})

$$\text{NAR}= \frac{(W2 - W1)(\text{Log L2}-\text{Log L1})}{(t2 - t1)(L1-L2)}$$

Where L_1 and L_2 are total leaf are at time t_1 and t_2 respectively. W_1 and W_2 are total dry wt. time t_1 and t_2 respectively.

2.3 Statistical Analysis

Data were analysed using SPSS for analysis of variance and Fisher's LSD multiple range test was employed for the means comparisons.

3. RESULTS AND DISCUSSION

3.1 Leaf Area Index (LAI)

The perusal of the results in Table 1 suggested that the highest LAI of 0.75, 0.88, 1.22 and 1.87, respectively observed in treatment where inorganic source of nutrient (M_1) was applied, it was significantly superior over integrated sources of nutrient (M_3) and organic sources of nutrient (M_2) at 21, 45, 60 and 90 DAS. Application of M_3 with the LAI of 0.67, 0.86, 0.95 and 1.67, respectively was also found significantly superior over organic sources of nutrient (0.39, 0.47, 0.55 and 1.61, respectively) at each stage. The increase was 92.30, 87.23, 121.81 and 16.14 per cent & 71.79, 57.37, 94.54 and 3.72 per cent respectively, due to M_1 and M_3 over M_2 at all the respective stages.

Among the nutrient levels, LAI increased from 0. 50, 0.65, 0.74 and 1.58 in S_1 (control) to 0.71, 0.96, 1.23 and 2.06 in S_4 (200% RDF) at 21, 45, 60 and 90 DAS, respectively. Application of S_4 (200% RDF) obtained significantly higher LAI over S_2 (100% RDF) and S_5 (STV based RDF) and it was on par with S_3 (150% RDF) at each growth stage. However, the application of S_3 (150% RDF) significantly increased LAI over S_2 (100% RDF) and S_5 (STV based RDF) at each growth stages except S_3 at milking stage. Application of S_2 (100% RDF) was also found significant over S_5 (STV based RDF) at 21, 45 and 60 DAS. The magnitude of increase was 42.0, 57.37, 89.23 and 66.12 per cent, respectively & 38.0, 45.90, 70.76 and 37.09 per cent, respectively due to application of S_4 (200% RDF) and S_3 (150% RDF) over control at all growth stages.

Interaction effect of different sources of nutrient and NPK levels were found to be significant overall growth stages. At 21 DAS, maximum value found in combination of M_1S_4 (0.92) which was found significant over all combinations but found at par with M_1S_3 (0.87) and M_3S_4 (0.87). All levels of different sources of nutrient were found significant over their control. At 45 DAS, highest LAI found with M_1S_4 (1.22) which was found significant over all treatments and followed by M_1S_3 (1.06), M_3S_4 (1.09) and M_3S_3 (1.09) these treatments were found at par among themselves. At 60 DAS, maximum values found in M_3S_4 (1.86) which was found significant over all combinations. However, the application of M_1S_3 (1.58) also found significant over all combinations. At 90 DAS, maximum values found under M_1S_4 (2.47) which was at par with M_1S_5 (2.16), M_3S_4 (1.98), M_1S_5 (1.90) and M_1S_3 (1.86) followed by remaining treatments.

The leaf area (LA) is a central factor for plant growth studies because it represents the surface that receives radiation, triggering the photosynthetic process on which the production of plant biomass depends and consequently, agricultural production [19, 20]. Increase leaf area in inorganic fertilizers and different NPK levels may be due to nitrogen application boosted the photosynthetic rate, leaf expansion and leaf persistency. As leaf area directly relates to the rate as well as duration of leaf expansion, so LAI finds to be sensitive to N availability to crop plants [21]. Soldati et al. [22] reported that an increase in dry matter accumulation leads to an increase in leaf area because proportion of dry matter allocated to leaves remain constant while an increase in leaf area leads to an increase in rate of dry matter accumulation because light interception is directly related to leaf area during this phase of development. N at highest rates increases the tissue formation with better plant growth which increases its concentration in leaves and results in higher LAI. As leaf area directly relates to the rate as well as duration of leaf expansion, so LAI finds to be sensitive to N availability to crop plants [21].

3.2 Crop Growth Rate (CGR)

Data has been presented in Table 2 indicated that the treatment where inorganic source of nutrient (M_1) was applied registered the highest crop growth rate (CGR) of 1.35, 3.13 and 21.45 g^{-1} m^{-2} day^{-1}, respectively which was significantly better than integrated sources of nutrient (M_3) and organic sources of nutrient (M_2) at 21-45, 45-60 and 60-90 DAS. The CGR of 1.24, 3.07 and 20.52 g^{-1} m^{-2} day^{-1} recorded in M_3 was also found significantly superior over M_2 which registered the lowest CGR (1.17, 2.74 and 20.01 g^{-1} m^{-2} day^{-1}), respectively at each stage. The response of increase was 15.38, 14.23 and 7.19 per cent respectively and 5.98, 12.04 and 2.54 per cent, respectively due to M_1 and M_3 over M_2 at each stage.

Among the different levels of NPK the crop growth rate (CGR) increased from 1.07,2.38 and 19.43 g^{-1} m^{-2} day^{-1}, respectively in S_1 (control) to 1.38, 3.25 and 21.70 g^{-1} m^{-2} day^{-1} in S_4 (200% RDF) at each stage. However, the application of S_4 (200% RDF) significantly increased over S_2 (100% RDF) and S_5 (STV based RDF) at all growth stages and found at par with S_3 (150% RDF) which registered the CGR of 1.34, 3.17 and 21.03 g^{-1} m^{-2} day^{-1}. Effect of S_2 (100% RDF) and S_5 (STV based RDF) for CGR was significantly similar with each other at each stage. The increase was up to 28.97, 36.55 and 11.68 percent respectively and 25.32, 33.19 and 8.23 per cent, respectively due to S_4 (200% RDF) and S_3 (150% RDF) over control at each stage. The lowest crop growth rate (CGR) values were recorded during early vegetative growth stages but increased to maximum during the flowering stage which is like the reports of other workers [23, 24, 5]. The significant increase in CGR due to combined NPK fertilizer nutrition might be owing to better availability of nutrients and effective conversion of macronutrients at the site of photosynthesis into pigments [25]. In fact, the combined function of NPK nutrients might have maximum photosynthate accumulation towards the leaf biomass, because in the initial stage, leaf is the more powerful sink than any other plant parts in most of the crops [26]. Thus, the number of leaves $plant^{-1}$ justified the ultimate final expression of growth parameters of the growing plants.

Kumar et [27] reported that increasing the fertilizer doses 150% RDF have brought increment in growth indices (plant height, tillers, DM, LAI, CGR, RGR, NAR, photosynthetic rate).

Table 1. Effect of different sources and NPK levels on LAI at different growth stages

M/S	LAI															
	21 DAS				45 DAS				60 DAS				90 DAS			
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	0.60	0.37	0.54	**0.50**	0.68	0.42	0.74	**0.61**	0.74	0.45	0.77	**0.65**	1.35	1.35	1.03	**1.24**
S2	0.71	0.45	0.68	**0.61**	0.75	0.49	0.78	**0.67**	1.41	0.52	0.83	**0.92**	1.79	1.48	1.53	**1.60**
S3	0.87	0.46	0.73	**0.69**	1.06	0.54	1.09	**0.89**	1.58	0.55	1.20	**1.11**	1.86	1.58	1.66	**1.70**
S4	0.92	0.40	0.81	**0.71**	1.22	0.56	1.09	**0.96**	1.25	0.59	1.86	**1.23**	2.47	1.72	1.98	**2.06**
S5	0.65	0.27	0.56	**0.49**	0.70	0.33	0.59	**0.54**	1.10	0.64	0.70	**0.81**	1.90	1.90	2.16	**1.99**
Mean	**0.75**	**0.39**	**0.67**	**0.60**	**0.88**	**0.47**	**0.86**	**0.74**	**1.22**	**0.55**	**1.07**	**0.95**	**1.87**	**1.61**	**1.67**	**1.72**
SEm±	0.028				0.027				0.023				0.088			
CD(p=0.05)	**0.110**				**0.106**				**0.089**				**NS**			
SEm±	0.023				0.025				0.026				0.069			
CD(p=0.05)	**0.066**				**0.073**				**0.075**				**0.202**			
Int I	0.039				0.043				0.045				0.120			
	0.114				**0.126**				**0.130**				**0.349**			
Int II	0.066				0.066				0.060				0.206			
	0.193				**0.194**				**0.176**				**0.601**			

M_1- Inorganic sources (NPK fertilizers), M_2- organic sources (FYM, vermicompost, biofertilizers Azotobacter and PSB) and M_3- Integrated sources (50% Inorganic + 50% organic) as main treatments and 5 NPK levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value (STV) for target yield of 6t ha^{-1}

Table 2. Effect of different sources and NPK levels on CGR at different growth stages

M/S	CGR (g^{-1} m^{-2} day^{-1})											
	21-45 DAS				45- 60 DAS				60- 90 DAS			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	1.05	1.07	1.09	**1.07**	2.38	2.41	2.36	**2.38**	19.10	19.96	19.24	**19.43**
S_2	1.35	1.16	1.22	**1.25**	3.18	2.67	3.17	**3.01**	21.66	19.70	20.55	**20.64**
S_3	1.49	1.23	1.30	**1.34**	3.41	2.80	3.30	**3.17**	22.01	20.25	20.82	**21.03**
S_4	1.54	1.24	1.36	**1.38**	3.45	2.90	3.40	**3.25**	22.76	20.61	21.71	**21.70**
S_5	1.32	1.14	1.22	**1.22**	3.24	2.90	3.10	**3.08**	21.71	19.55	20.26	**20.51**
Mean	**1.35**	**1.17**	**1.24**	**1.25**	**3.13**	**2.74**	**3.07**	**2.98**	**21.45**	**20.01**	**20.52**	**20.66**
SEm±	0.035				0.058				0.253			
CD(p=0.05)	**0.136**				**0.228**				**0.994**			
SEm±	0.042				0.068				0.249			
CD(p=0.05)	**0.124**				**0.199**				**0.726**			
Int I	0.074				0.118				0.431			
	NS				**NS**				**NS**			
Int II	0.095				0.157				0.636			
	NS				**NS**				**NS**			

M_1- Inorganic sources (NPK fertilizers), M_2- organic sources (FYM, vermicompost, biofertilizers Azotobacter and PSB) and M_3- Integrated sources (50% Inorganic + 50% organic) as main treatments and 5 NPK levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value (STV) for target yield of 6t ha^{-1}

Table 3. Effect of different sources and NPK levels on RGR at different growth stages

M/S	RGR (g^{-1} m^{-2} day^{-1})											
	21-45 DAS				45- 60 DAS				60- 90 DAS			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	0.0594	0.0581	0.0590	**0.0588**	0.0183	0.0180	0.0187	**0.0183**	0.0153	0.0151	0.0154	**0.0153**
S_2	0.0652	0.0606	0.0615	**0.0624**	0.0231	0.0218	0.0229	**0.0226**	0.0173	0.0146	0.0164	**0.0161**
S_3	0.0731	0.0608	0.0665	**0.0668**	0.0257	0.0232	0.0237	**0.0242**	0.0191	0.0167	0.0173	**0.0177**
S_4	0.0735	0.0614	0.0670	**0.0673**	0.0264	0.0230	0.0246	**0.0247**	0.0191	0.0167	0.0186	**0.0181**
S_5	0.0701	0.0605	0.0616	**0.0641**	0.0245	0.0209	0.0227	**0.0227**	0.0180	0.0163	0.0169	**0.0171**
Mean	**0.0683**	**0.0603**	**0.0631**	**0.0639**	**0.0236**	**0.0214**	**0.0225**	**0.0225**	**0.0178**	**0.0159**	**0.0169**	**0.0168**
SEm±	0.0014				0.0004				0.0003			
CD(p=0.05)	**0.0056**				**0.0016**				**0.0010**			
SEm±	0.0011				0.0002				0.0003			
CD(p=0.05)	**0.0031**				**0.0005**				**0.0008**			
Int I	0.0019				0.0014				0.0005			
	NS				**NS**				**NS**			
Int II	0.0033				0.0025				0.0007			
	NS				**NS**				**NS**			

M_1- Inorganic sources (NPK fertilizers), M_2- organic sources (FYM, vermicompost, biofertilizers Azotobacter and PSB) and M_3- Integrated sources (50% Inorganic + 50% organic) as main treatments and 5 NPK levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value (STV) for target yield of 6t ha^{-1}

Table 4. Effect of different sources and NPK levels on NAR at different growth stages

M/S	**NAR** (g^{-1} m^{-2} day^{-1})											
	21-45 DAS				**45- 60 DAS**				**60- 90 DAS**			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
S_1	0.0151	0.0155	0.0154	**0.0153**	0.0116	0.0123	0.0114	**0.0118**	0.0111	0.0113	0.0115	**0.0113**
S_2	0.0171	0.0155	0.0168	**0.0165**	0.0129	0.0130	0.0129	**0.0129**	0.0126	0.0122	0.0126	**0.0125**
S_3	0.0189	0.0158	0.0171	**0.0172**	0.0157	0.0130	0.0142	**0.0143**	0.0152	0.0125	0.0139	**0.0139**
S_4	0.0193	0.0162	0.0178	**0.0178**	0.0160	0.0133	0.0146	**0.0147**	0.0158	0.0126	0.0144	**0.0143**
S_5	0.0175	0.0158	0.0170	**0.0168**	0.0142	0.0129	0.0129	**0.0133**	0.0141	0.0124	0.0124	**0.0130**
Mean	**0.0176**	**0.0158**	**0.0168**	**0.0167**	**0.0141**	**0.0129**	**0.0132**	**0.0134**	**0.0138**	**0.0122**	**0.0130**	**0.0130**
SEm±	0.0002				0.0002				0.0002			
CD(p=0.05)	**0.0010**				**0.0009**				**0.0009**			
SEm±	0.0003				0.0002				0.0002			
CD(p=0.05)	**0.0008**				**0.0007**				**0.0007**			
Int I	0.0005				0.0004				0.0004			
	NS				**0.0012**				**0.0012**			
Int II	0.0007				0.0006				0.0006			
	NS				**0.0017**				**0.0016**			

M_1- Inorganic sources (NPK fertilizers), M_2- organic sources (FYM, vermicompost, biofertilizers Azotobacter and PSB) and M_3- Integrated sources (50% Inorganic + 50% organic) as main treatments and 5 NPK levels S_1- control, S_2- 100% RDF, S_3- 150% RDF, S_4- 200% RDF, S_5- Based on soil test value (STV) for target yield of 6t ha^{-1}

3.3 Relative Growth Rate (RGR)

Data presented in the Table (3) revealed that the significantly maximum value of relative growth rate (RGR) of 0.0683, 0.0236 and 0.0178 g^{-1} m^{-2} day^{-1} was recorded with the application of inorganic sources of nutrient (M_1) which proved its significant superiority over integrated sources of nutrient (M_3) and organic sources of nutrient (M_2) at 21-45, 45-60 and 60-90 DAS. The addition of M_3 also gave significantly higher value of RGR which was 0.0225, 0.0631 and 0.0169 g^{-1} m^{-2} day^{-1}, respectively over M_2 with the lowest RGR of 0.0603, 0.0214 and 0.0159 g^{-1} m^{-2} day^{-1}, respectively at each stage. Application of M_1 and M_3 accounted 13.26, 10.28, 11.94 per cent, respectively and 4.64, 5.14 and 6.28 per cent, respectively increase over M_2 at each stage.

The RGR increases from 0.0588, 0.0183 and 0.0153 g^{-1} m^{-2} day^{-1} in S_1 (control) to 0.0673, 0.0247 and 0.0181 g^{-1} m^{-2} day^{-1} in S_4 (200% RDF) at 21-45, 45-60 and 60-90 DAS. However, the application of S_3 (150% RDF) and S_4 (200% RDF) significantly increased RGR over S_2 (100% RDF) and S_5 (STV based RDF) at each growth stages. Highest RGR was obtained in S_4 (200% RDF), which was significantly similar with S_3 (150% RDF) with the RGR of 0.0668, 0.0242 and 0.0177 g^{-1} m^{-2} day^{-1} respectively. Effect of S_2 (100% RDF) and S_5 (STV based RDF) was found at par with each other at each stage. The corresponding increase was 14.45, 34.97 and 13.83 per cent, respectively and 13.60, 32.24 and 11.32 per cent, respectively due to S_4 (200% RDF) and S_3 (150% RDF) at each stage.

Relative growth rate (RGR) expresses the dry weight increase in time interval in relation to the initial weight N fertilizers, which might be due to the high concentrations of nutrients in fairly fertilized plots causing production of more leaves which in turn contributes for the production of high dry matter which resulted in more RGR [28]. The phenomena of RGR tend to be low again during later stage and negative towards maturity considerably due the amount of CO_2 lost by respiration, which occurs uninterruptedly in all metabolically active tissues, was greater than that assimilated by photosynthesis which occurs only in cells with chlorophyll when exposed to light [29]. These results are in agreement with those obtained by [30, 31, 32].

3.4 Net Assimilation Rate (NAR)

Data presented in Table 4 indicated that the among the different sources, inorganic sources of nutrient showed significant superiority with the NAR of 0.0176, 0.0141 and 0.0138 g^{-1} m^{-2} day^{-1} over integrated sources of nutrient (M_3) and organic source of nutrients (M_2) at 21-45, 45-60 and 60-90 DAS. Application of M_3 registered comparatively higher NAR of 0.0168, 0.0132 and 0.0130 g^{-1} m^{-2} day^{-1} over M_2, which have lowest NAR of 0.0158, 0.0129 and 0.0122 g^{-1} m^{-2} day^{-1} at each stage. Increase in NAR of 11.39, 2.32 and 13.11 per cent respectively and 6.32, 9.30 and 6.55 respectively in response to M_1 and M_3 over M_2 at each stage.

The NAR increased from 0.0153, 0.0118 and 0.0113 g^{-1} m^{-2} day^{-1} in S_1 (control) to 0.0178, 0.0147 and 0.0143 g^{-1} m^{-2} day^{-1} in S_4 (200% RDF) at 21-45, 45-60 and 60-90 DAS. However, the application of S_3 (150% RDF) and S_4 (200% RDF) significantly increased NAR over S_2 (100% RDF) and S_5 at each growth stages. The treatment receiving S_4 (200% RDF) obtained the maximum NAR which was significantly similar with S_3 (150% RDF), with the resultant value of 0.0172, and 0.0143 and 0.0139 g^{-1} m^{-2} day^{-1}. The NAR of S_2 (100% RDF) and S_5 were found at par with each other. The increase in NAR over control was 16.33, 24.57 and 26.54 per cent respectively and 12.41, 23.00 and 21.18 per cent, respectively in response to S_4 (200% RDF) and S_3 (150% RDF) at each stage.

Interaction effect was nonsignificant at 21-45 DAS but found significant at 45-60 DAS and 60-90 DAS. At 45-60 DAS, maximum NAR found with the application of M_1S_4 (0.0160 g^{-1} m^{-2} day^{-1}) which was found at par with M_1S_3 (0.0157 g^{-1} m^{-2} day^{-1}) and M_3S_4 (0.0146 g^{-1} m^{-2} day^{-1}) followed by remaining treatments. At 60-90 DAS maximum values found under M_1S_4 (0.0158) which was found over all treatment but found at par with M_1S_3 (0.0158 g^{-1} m^{-2} day^{-1}) and M_3S_4 (0.0144) followed by remaining treatments. NAR is a measure of the rate of dry matter accumulation per unit leaf area. An increase in NAR during the growing season is indicative of response of the photosynthetic apparatus to an increase in demand for assimilates to afford rapid growth of the grain fraction [24]. Portes reported that [29] NAR decrease with maturity because the loss of CO_2 by respiration exceeded the amount assimilated for photosynthesis. Elevated nitrogen supply can boost dry matter content through production of photo-assimilates via leaves which is the centre of plant growth during vegetative stage and later distribution of assimilates to the reproductive organs [24]. The low net assimilation rate might be due to restricted availability of essential nutrients and decreased photosynthetic efficiency [33].

4. CONCLUSION

A result obtained from present investigation indicates that application of different sources of nutrients and varied levels of NPK fertilizers significantly influences the growth and growth attributes of wheat. Adequate supply of plant nutrient in inorganic sources with 150% RDF levels helps in better photosynthesis and growth of wheat which helps in higher yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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