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Effect of wheat [*Treticum aestivum* (L.)] varieties under fertility levels and seed rates on physiological parameter, nutrient content and uptake of crop plant

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Abstract
A field experiment was conducted during 2013-14 and 2014-15 at research farm, RVSKVV, College of Agriculture, Gwalior, Madhya Pradesh. The experiment involve thirty treatment combinations consisting of two varieties *viz*. V_1: RVW 4106 and V_2: MP 4010 as well as three seed rates *viz*. S_1: 100 kg/ha; S_2: 125 kg/ha and S_3: 150 kg/ha and five fertility levels i.e. F_1: 50% RDF + 10 tonnes FYM/, F_2: 75% RDF + 5 tonnes FYM/ha, F_3: 100% RDF, F4: 125% RDF and F_5: 150% RDF in factorial R.B.D with 3 replications. The result revealed that the maximum physiological parameter and N, P and K content and uptake were recorded under the variety MP 4010 as compared to RVW 4106. Seed rate 150 kg ha^{-1} gave significantly highest NPK uptake as compared to 125 and 100 seed kg ha^{-1} whereas maximum physiological parameter were non-significant under seed rates levels. Fertility level, 75% RDF + 5 tonnes FYM ha^{-1} gave significantly higher content and uptake of N, P and K nutrient by crop as well as maximum physiological parameter.

Keywords: Fertility levels, seed rates, physiological parameter, nutrient content and uptake and varieties

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important cereal crops of India. There has been tremendous increase in area, production and productivity of this crop during the green revolution phase of Indian agriculture. It occupies second position in terms of both area and production in our country. It is cultivated in area of 29.50 million hectares with annual production of 93.62 million tonnes and productivity of 3140 kg/ha in 2011-12, whereas, in Madhya Pradesh, it is cultivated in 49.50 lakh ha. Land with an annual production of 134.15 lakh tonnes with productivity of 2710 kg/ha [1].

Wheat is the main cereal crop in India. The total area under the crop is about 29.8 million hectares in the country. The production of wheat in the country has increased significantly from 75.81 million MT in 2006-07 to an all-time record high of 94.88 million MT in 2011-12. The productivity of wheat, which was 2602 kg/ha in 2004-05 has increased to 3140 kg/ha in 2011-12. The major increase in the productivity of wheat has been observed in the states of Haryana, Punjab and Uttar Pradesh. Higher area coverage is reported from MP in recent years [1].

Although the latest production technologies have increased the area and productivity, there are many factors that lowers the crop production potential. Late sowing of the crop is also a major factor for the low production potential. Intensive cropping, inclusion of one short duration crop after kharif crop, late maturity of kharif crop due to rains, late picking of cotton in cotton belts, reduced supply of irrigation water at the sowing time and delayed supply of seeds to farmers are some reasons for the late sowing of crop. Planting time, physiological parameter such as LAI, NAR, CGR etc. Along with variety selection have also an important impact on obtaining better crop output. These factors not only affect productivity, but also crop growth behaviour, number of tillers, number of grains per spike and eventually the crop production potential.

In cotton-wheat belt wheat sowing is delayed due to late maturing cotton varieties and final picking goes up to December and even January. Heavy insect pest infestation particularly mealy bug attacks also force the problems to get the more pickings and delay their cotton harvesting, so that additional returns may be snatched which in turn results in late sowing of wheat in this belt.

The level of self – sufficiency will not be achieved unless researchers manage to make better use of resources and new technology transfer. There is a concerted effort to significantly improve the physiological parameter in wheat so that higher production potential to be achieved.

Many high yielding varieties have been evolved and recommended for general cultivation in the past. These varieties are losing their yield potential due to change of various edaphic and environmental conditions. Therefore continuous selection of high yielding genotypes with mid-range of adaptability to edaphic and environmental conditions is very essential to increase yield per hectare.

The Indian farmers have been using old and inefficient methods and techniques of production generation after generation. Increase in production is possible only if proper and adequate manures are used. However, in India, the use of both farmyard manures and chemical fertilizer is mostly inadequate compared to our needs. The importance of good quality seeds to increase agricultural productivity hardly requires any emphasis. However, Indian farmers have been using seeds of very poor quality for decades. In addition, farmers are not applying well decomposed farmyard manure or compost to increase fertility of the soils.

The integrated nutrient management helps to restore and sustain fertility and crop productivity. It may also help to check the emerging deficiency of nutrients other than N, P, K and further, it brings economy and efficiency in fertilizers. The integrated nutrient management favorably affects the physical, chemical and biological environment of soil.

Considering the above fact therefore there is a need to judge the Effect of wheat [*Treticum aestivum* (L.)] varieties under fertility levels and seed rates on physiological parameter, nutrient content and uptake of crop plant.

Method and materials

The present experiment entitled "Effect of recent wheat [*Treticum aestivum* (L.)] Varieties in various fertility levels and seed rates under late sown condition" was carried out during two consecutive Kharif seasons of 2013-14 and 2014-15 at research farm, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, College of Agriculture, Gwalior, Madhya Pradesh. The experimental soil was sandy clay loam in texture, with pH 7.58, EC 0.44 dSm^{-1}, Organic carbon 0.43% with available N (167.00 kg ha^{-1}), P_2O_5 (14.60 kg ha^{-1}) and K_2O (239.30 kg ha^{-1}). The study involve thirty treatment combinations consisting of two varieties *viz.* V_1: RVW 4106 and V_2: MP 4010 as well as three seed rates *viz*. S_1: 100 kg/ha; S_2: 125 kg/ha and S_3: 150 kg/ha and five fertility levels i.e. F_1: 50% RDF + 10 tonnes FYM/, F_2: 75% RDF + 5 tonnes FYM/ha, F_3: 100% RDF, F4: 125% RDF and F_5: 150% RDF in factorial R.B,D design with 3 replications.

The experimental field was prepared properly in the second and third week of December 2013-14 and 2014-15, respectively after pre-sowing irrigation. When soil became workable, the field was ploughed with disc plough followed by two tillage operations by cultivators. Later on the field was leveled by plank. Nitrogen was applied in the form of urea (46% N) as per treatments. Single super-phosphate (16% P_2O_5) and murate of potash (60% K_2O) were used as sources for P_2O_5 and K_2O, respectively. Recommended doses of NPK for wheat was 120:60:40 kg/ ha, respectively. Full quantities of P and K fertilizers and half quantity of N fertilizer were mixed together and placed about 3-4 cm below the seed in the furrow at the time of sowing. Well decomposed FYM was added to the plots as per treatment and mixed with last tillage operation. Further, half dose of nitrogen was applied as top dressing after first irrigation. Seeds were sown as per treatments by funnel attached with desi plough, keeping row to row distance of 20 cm. The sowing was done on 22th December, 2013 in the first year of experiment and on 21th December, 2014 and 2014, in the second year of experiment. Total four irrigations (7.5 cm each) were given to the crop each year. Two hand weedings were done at 30 and 45 days after sowing respectively.

The periodical observations were recorded on physiological parameters studies and the following methods were used for recording various observations in the field and laboratory as per prescribed procedures as;

Crop growth rate (CGR)

Crop growth rate (CGR) was worked out by adopting the formula of Watson (1952) [15] and expressed as $g/m^2/$ day.

$$CGR = \frac{w_2 - w_1}{t_2 - t_1}$$

Where,
w1 =dry weight (g/m^2) at t1,
w2 =dry weight (g/m^2) at t2
t1 = time of first observation
t2 = time of second observation

Relative growth rate (RGR)

The relative growth rate was calculated by the formula of Blackman (1919) [2] and expressed as g /g /day

$$RGR = \frac{Log_e w_2 - Log_e w_1}{t_2 - t_1}$$

Where,
w1 =dry weight (g) / plant at t1,
w2 =dry weight (g)/ Plant at t2
t1 = time of first observation
t_2 = time of second observation

Absolute Growth Rate (AGR)

Absolute growth rate (AGR) is the dry matter production per unit time (g/day), which was calculated by using the formula as given by Radford (1967) [10].

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,
W_1 = Dry weight of the plant (g) at time t_1
W_2 = Dry weight of the plant (g) at time t_2
t1 = time of first observation
t_2 = time of second observation

Leaf area Index (LAI)

The leaf area index (LAI) is the ratio of leaf area per plant to the land area occupied by the plant and calculated by using the formula as suggested by (Sestak *et al*., 1971) [11].

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area per plant } (m^2)}{\text{Land area occupied by a plant } (m^2)}$$

Leaf area duration (LAD)

Leaf area duration (LAD) is the relation of potential green leaf area for a particular period and worked out by the formula as suggested by Power *et al.* (1967) [9] and expressed in days.

$$LAD = \frac{LA_2 + LA_1(t_2 - t_1)}{2}$$

LA_1 and LA_2 – Leaf area at time t_1 and t_2 respectively. If LAI is plotted against time, it produces a function that indicates assimilatory capacity of crop during the period.

Net Assimilation Rate (NAR)

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time, which was calculated by the formula as adopted by Gregory (1926) [4] and expressed as $gdm^{-2}\,day^{-1}$.

$$NAR = \frac{(W_2 - W_1)(\log_e LA_2 - \log_e LA_1)}{(t_2 - t_1)(LA_2 - LA_1)}$$

Leaf Area Ratio (LAR)

Leaf area ratio (LAR) is the ratio of the total leaf area to the whole plant dry weight and is a further measure of the efficiency of leaf surface in producing dry matter. It is expressed as dm^2/g.

$$LAR = \frac{(LA_1/W_1) + (LA_2/W_2)}{2}$$

Plant NPK content (%) as well as uptake (kg/ha) were determined as per the standard methods. Data were analyzed as per standard procedure with 5% probability level.

Result and Discussion

Physiological parameters

The data related to physiological parameters were presented in table 1 to 8. Growth analysis technique has made substantial contribution to the current understanding of the physiological basis of yield variation in different crops.

Efforts to relate crop yields to canopy architecture began in the early 20th century with the development of "growth analysis" by British plant physiologists. They recorded total plant dry weight (W) and leaf area (L) in the growing season.

In fact leaf is the factory for the conversion of solar energy into the chemical energy for the growth and development of plants. Leaf area or photosynthetic area fairly gives a good idea of the photosynthetic capacity of the plant. The LAI, LAR, LAD, NAR, CGR, RGR and AGR are the important growth parameters influencing yield which are dependent not only on the genotype but also on the environmental and fertility management practices.

Varietal treatments significantly affected LAI, LAR, LAD, NAR, CGR, RGR and AGR at different stages of observation. Among these parameters, LAI, LAD, CGR and AGR increased up to 90 DAS; RGR up to 60 DAS and decreased thereafter due to senescence and aging of leaves as well as complicated physiological functions in the plant. These results are in line with the findings of Sharma *et al.* (2016) [12] who reported that LAI, LAD, CGR and AGR of wheat increased up to 90 DAS and RGR up to 60 DAS Leaf area index (LAI) increased from 30-90 DAS and decreased from 90 DAS to maturity stage. The higher LAI, LAD, CGR, RGR and AGR was recorded with variety MP 4010 over variety RVW 4106. However, Highest LAR and NAR was achieved with variety RVW 4106. The varietal differences amongst these growth analysis parameters attributed to the variability in the genetic inheritance among the varieties. This has been supported by Tripathi and Verma (2007) [14] and Laghari *et al.* (2011) [5].

Leaf area index (LAI), leaf area ratio (LAR), leaf area duration, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) and absolute growth rate (AGR) were also influenced amongst seed rates treatments at different crop growth stages. The maximum LAI and LAD recorded with 125 kg/ha seed rate at all the stages.

Leaf area ratio indicates the size of assimilatory surface area in relation to total dry matter accumulation. The LAR was more during early stages of crop growth and decreased towards maturity. At 30 DAS, Highest value of LAR was noted with 125 kg/ha seed rate but at maturity stage, it was found highest with 150 kg/ha seed rate. Lowest LAR was obtained with 100 kg /ha seed rate.

NAR was significantly influenced due to different seed rate treatments at all stages of crop growth except at maturity stage. The NAR (net assimilation rate) values were higher at early growth stage and then declined with the advancement in growth stage up to maturity stage. The maximum NAR value was noted with crop sown 100 kg/ha seed rate at 30 and 90 DAS. However, at 60 DAS, higher NAR value was found with 125 kg/ha, seed rate followed by 10 kg/ha seed rate. It may possible due to lower competition amongst crop plant for light, moisture, space and nutrients.

Crop growth rate (CGR) and absolute growth rate (AGR) was also influenced by different seed rates treatments at all crop growth stages except 30 DAS. The maximum CGR and AGR was obtained with 125 kg/ha seed rate at 30 DAS and but at 90 DAS and maturity stages, it was found highest with 100 kg/ha seed rate. It may possible due to lesser competition amongst crop plant. These results also corroborate with the finding of Laghari *et al.* (2011) [5].

Relative growth rate (RGR) indicates rate of growth per unit dry matter. The RGR was lower at early stages and increased up to 60 DAS thereafter it was decreased toward maturity stages These results are in line with the findings of Shukla and Warsi (2002)[13] who reported that maximum RGR of wheat at 35- 45 DAS. Seed rate treatments significantly influenced this parameter at 60 DAS. The maximum value of RGR was noted in 125 kg/ha seed rate while minimum with 150 kg/ha seed rate, Minimum RGR under 150 kg/ha may be due to higher competition amongst crop plant.

Fertility levels caused a marked variation in growth parameters of wheat at most of the crop growth stages. The growth analysis parameters, *viz.*, LAI, LAR, LAD, NAR, CGR, RGR and AGR had a direct relationship with the fertility levels. Therefore the maximum values of these growth parameters except LAR were recorded with the 75% RDF + 5 tonnes FYM/ha followed by 125% RDF and 150% RDF. These findings are in close agreement with previous finding of Shukla and warsi (2002) [13] who reported that LAI, LAR, NAR and RGR were higher at high fertility level.

It may be due to more availability and absorption of nutrients caused more cell elongation, development and root development, which ultimately increased growth and yield of crop. Maximum leaf area was noticed at 60-90 days after sowing. After 90 DAS, there was reduction in leaf area toward maturity due to leaf shedding while LAR was highest at 30 DAS. It may be due to larger contribution of leaf to total dry matter at this stage. Laghari *et al.* (2010) [6] also reported

that fertilizer rates significantly enhanced LAI and CGR of wheat. Net assimilation rate (NAR), synonymously called as "unit leaf rate", and expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface area. Watson (1952) [15] suggested that NAR does not measure real photosynthates but represents net result of photosynthetic gain over respiratory loss and it gives no direct indications of respiratory losses.

Table 1: Leaf area index (LAI) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		LAI at											
		30 DAS			60 DAS			90 DAS			Harvest		
Varieties	Sy.	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RVW 4106	V_1	1.757	1.752	1.754	4.066	4.026	4.046	5.286	5.229	5.257	1.790	1.799	1.795
MP 4010	V_2	1.783	1.777	1.780	4.260	4.245	4.252	5.498	5.475	5.486	1.803	1.809	1.806
S.E. m (d) ±		0.008	0.009	0.006	0.055	0.057	0.039	0.064	0.068	0.047	0.009	0.010	0.007
C.D. (at 5%)		0.023	0.024	0.017	0.152	0.157	0.109	0.178	0.190	0.130	NS	NS	NS
Seed rates													
100 kg/ha	S_1	1.745	1.741	1.743	4.226	4.211	4.218	5.503	5.468	5.486	1.803	1.804	1.804
125 kg/ha	S_2	1.801	1.794	1.798	4.242	4.207	4.225	5.545	5.495	5.520	1.815	1.832	1.824
150 kg/ha	S_3	1.763	1.759	1.761	4.021	3.988	4.004	5.127	5.092	5.109	1.772	1.775	1.774
S.E. m (d) ± C.D. (at 5%)		0.010	0.011	0.007	0.067	0.069	0.048	0.079	0.084	0.057	0.011	0.012	0.008
		0.028	0.030	0.020	0.186	0.192	0.134	0.218	0.233	0.159	0.030	0.033	0.022
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	1.735	1.726	1.731	3.771	3.756	3.763	4.825	4.765	4.795	1.780	1.784	1.782
75% RDF + 5 tonnes FYM /ha	F_2	1.820	1.812	1.816	4.505	4.480	4.492	5.924	5.891	5.908	1.868	1.876	1.872
100% RDF	F_3	1.761	1.751	1.756	3.736	3.717	3.726	4.867	4.847	4.857	1.775	1.780	1.777
125% RDF	F_4	1.765	1.765	1.765	4.409	4.369	4.389	5.679	5.630	5.654	1.783	1.787	1.785
150% RDF	F_5	1.768	1.768	1.768	4.394	4.355	4.374	5.664	5.625	5.644	1.780	1.795	1.787
S.E. m (d) ± C.D. (at 5%)		0.013	0.014	0.010	0.087	0.090	0.062	0.101	0.108	0.074	0.014	0.015	0.010
		0.037	0.038	0.026	0.240	0.248	0.173	0.281	0.300	0.206	0.039	0.042	0.029
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Leaf area ratio (LAR) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		LAR (cm^2/g) at											
		30 DAS			60 DAS			90 DAS			Harvest		
Varieties	Sy.	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RVW 4106	V_1	80.70	80.16	80.43	51.45	50.75	51.10	35.45	35.01	35.23	10.85	11.01	10.93
MP 4010	V_2	81.12	81.23	81.17	52.24	52.30	52.27	36.05	35.93	35.99	10.61	10.71	10.66
S.E. m (d) ±		0.56	0.60	0.41	0.78	0.73	0.54	0.50	0.56	0.37	0.09	0.12	0.07
C.D. (at 5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS	0.25	0.33	0..21
Seed rates													
100 kg/ha	S_1	79.44	79.43	79.44	52.14	51.55	51.84	34.93	34.67	34.80	10.30	10.36	10.33
125 kg/ha	S_2	82.24	81.74	81.99	51.56	51.18	51.37	36.55	36.34	36.44	10.74	10.94	10.84
150 kg/ha	S_3	81.04	80.92	80.98	51.82	51.84	51.83	35.78	35.40	35.59	11.14	11.27	11.20
S.E. m (d) ± C.D. (at 5%)		0.69	0.65	0.47	0.96	0.90	0.66	0.61	0.68	0.46	0.11	0.14	0.09
		1.91	1.80	1.31	NS	NS	NS	NS	NS	1.27	0.31	0.40	0.25
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	82.01	80.98	81.49	52.15	51.11	51.63	36.21	35.59	35.90	11.91	12.03	11.97
75% RDF + 5 tonnes FYM /ha	F_2	81.63	80.45	81.04	51.80	51.23	51.51	34.88	34.59	34.73	9.89	9.96	9.93
100% RDF	F_3	81.24	82.02	81.63	49.17	49.15	49.16	34.09	34.40	34.25	11.15	11.36	11.26
125% RDF	F_4	80.26	80.03	80.15	51.75	51.89	51.82	35.60	35.18	35.39	10.02	10.11	10.07
150% RDF	F_5	79.39	80.00	79.70	54.34	54.25	54.29	37.98	37.60	37.79	10.65	10.83	10.74
S.E. m (d) ± C.D. (at 5%)		0.89	0.84	0.61	1.24	1.16	0.85	0.79	0.88	0.59	0.14	0.19	0.12
		NS	NS	NS	NS	NS	2.35	2.18	NS	1.64	0.40	0.52	0.33
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Leaf area duration (LAD) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		LAD (days) at											
		30 DAS			60 DAS			90 DAS			Harvest		
Varieties	Sy.	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RVW 4106	V_1	14.83	14.78	14.80	49.13	48.75	48.94	78.90	78.09	78.50	65.68	61.27	63.48
MP 4010	V_2	15.04	15.00	15.02	50.99	50.81	50.90	82.33	82.01	82.17	67.76	63.51	65.63
S.E. m (d) ± C.D. (at 5%)		0.07	0.07	0.05	0.47	0.49	0.34	0.94	0.98	0.68	0.60	0.62	0.43
		0.19	0.20	0.14	1.31	1.35	0.94	2.61	2.73	1.89	1.67	1.73	1.20
Seed rates													
100 kg/ha	S_1	14.73	14.69	14.71	50.38	50.22	50.30	82.09	81.67	81.88	67.81	63.41	65.61
125 kg/ha	S_2	15.20	15.14	15.17	51.00	50.63	50.81	82.59	81.86	82.22	68.32	63.89	66.10
150 kg/ha	S_3	14.88	14.84	14.86	48.80	48.49	48.65	77.19	76.61	76.90	64.04	59.87	61.95
S.E. m (d) ± C.D. (at 5%)		0.09	0.09	0.06	0.58	0.60	0.42	1.15	1.20	0.83	0.74	0.76	0.53
		0.24	0.25	0.17	1.61	1.66	1.16	3.20	3.34	2.31	2.04	2.12	1.47

Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	14.64	14.57	14.60	46.46	46.26	46.36	72.53	71.90	72.21	61.30	57.10	59.20
75% RDF + 5 tonnes FYM /ha	F_2	15.36	15.29	15.33	53.37	53.09	53.23	87.99	87.51	87.75	72.32	67.72	70.02
100% RDF	F_3	14.86	14.78	14.82	46.38	46.13	46.26	72.59	72.26	72.43	61.65	57.78	59.71
125% RDF	F_4	14.89	14.89	14.89	52.09	51.76	51.93	85.12	84.37	84.74	69.25	64.66	66.96
150% RDF	F_5	14.92	14.92	14.92	51.99	51.66	51.83	84.87	84.20	84.53	69.09	64.69	66.89
S.E. m (d) ±		0.11	0.12	0.08	0.75	0.77	0.54	1.49	1.55	1.08	0.95	0.99	0.69
C.D. (at 5%)		0.31	0.32	0.22	2.08	2.14	1.49	4.13	4.31	2.98	2.64	2.73	1.90
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Net assimilation rate (NAR) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		**NAR (g/m²/days) at**											
		30 DAS			**60 DAS**			**90 DAS**			**Harvest**		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	0.1901	0.1913	0.1907	0.0697	0.0703	0.0700	0.0504	0.0510	0.0507	0.0162	0.0147	0.0154
MP 4010	V_2	0.1896	0.1892	0.1894	0.0699	0.0697	0.0698	0.0493	0.0498	0.0495	0.0168	0.0160	0.0164
S.E. m (d) ±		0.0012	0.0013	0.0009	0.0010	0.0009	0.0007	0.0010	0.0011	0.0008	0.0008	0.0006	0.0005
C.D. (at 5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Seed rates													
100 kg/ha	S_1	0.1927	0.1927	0.1927	0.0704	0.0713	0.0708	0.0531	0.0532	0.0532	0.0170	0.0160	0.0165
125 kg/ha	S_2	0.1876	0.1886	0.1881	0.0710	0.0711	0.0711	0.0479	0.0483	0.0481	0.0165	0.0156	0.0160
150 kg/ha	S_3	0.1893	0.1895	0.1894	0.0681	0.0677	0.0679	0.0484	0.0496	0.0490	0.0160	0.0144	0.0152
S.E. m (d) ±		0.0014	0.0016	0.0011	0.0012	0.0011	0.0008	0.0012	0.0014	0.0009	0.0010	0.0007	0.0006
C.D. (at 5%)		0.0040	NS	0.0029	NS	0.0032	0.0023	0.0033	0.0039	0.0026	NS	NS	NS
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	0.1866	0.1887	0.1877	0.0651	0.0667	0.0659	0.0477	0.0478	0.0477	0.0163	0.0148	0.0155
75% RDF + 5 tonnes FYM /ha	F_2	0.1892	0.1919	0.1905	0.0733	0.0737	0.0735	0.0536	0.0540	0.0538	0.0167	0.0160	0.0164
100% RDF	F_3	0.1889	0.1869	0.1879	0.0692	0.0695	0.0694	0.0524	0.0522	0.0523	0.0164	0.0157	0.0161
125% RDF	F_4	0.1912	0.1920	0.1916	0.0732	0.0723	0.0727	0.0497	0.0512	0.0505	0.0166	0.0152	0.0159
150% RDF	F_5	0.1933	0.1918	0.1926	0.0683	0.0680	0.0682	0.0457	0.0469	0.0463	0.0164	0.0150	0.0157
S.E. m (d) ±		0.0018	0.0020	0.0014	0.0015	0.0015	0.0011	0.0016	0.0018	0.0012	0.0012	0.0010	0.0008
C.D. (at 5%)		NS	NS	0.0038	0.0042	0.0041	0.0029	0.0043	0.0045	0.0033	NS	NS	NS
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Crop growth rate (CGR) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		**CGR (g/m²/days) at**											
		30 DAS			**60 DAS**			**90 DAS**			**Harvest**		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	8.17	8.21	8.19	21.57	21.59	21.58	26.24	26.27	26.26	5.87	5.67	5.77
MP 4010	V_2	8.25	8.21	8.23	22.34	22.21	22.28	26.83	27.04	26.94	6.26	6.31	6.28
S.E. m (d) ±		0.04	0.04	0.03	0.25	0.20	0.16	0.46	0.51	0.34	0.13	0.19	0.11
C.D. (at 5%)		NS	NS	NS	0.70	0.56	0.45	NS	NS	NS	0.36	0.53	0.32
Seed rates													
100 kg/ha	S_1	8.24	8.23	8.24	22.19	22.39	22.29	28.76	28.68	28.72	6.34	6.30	6.32
125 kg/ha	S_2	8.22	8.24	8.23	22.70	22.58	22.64	26.12	26.13	26.13	6.20	6.22	6.21
150 kg/ha	S_3	8.16	8.16	8.16	20.98	20.73	20.86	24.73	25.16	24.94	5.66	5.45	5.55
S.E. m (d) ±		0.04	0.05	0.03	0.32	0.25	0.20	0.57	0.62	0.42	0.16	0.23	0.14
C.D. (at 5%)		NS	NS	NS	0.86	0.69	0.55	1.57	1.72	1.17	0.43	0.64	0.39
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	7.94	8.00	7.97	19.24	19.57	19.41	22.89	22.72	22.80	5.66	5.40	5.53
75% RDF + 5 tonnes FYM /ha	F_2	8.36	8.45	8.41	24.32	24.33	24.32	31.10	31.15	31.12	6.57	6.75	6.66
100% RDF	F_3	8.14	8.01	8.08	20.47	20.40	20.44	25.06	24.77	24.91	5.66	5.74	5.70
125% RDF	F_4	8.25	8.28	8.27	23.72	23.32	23.52	28.00	28.60	28.30	6.26	6.06	6.16
150% RDF	F_5	8.36	8.29	8.32	22.01	21.88	21.95	25.64	26.05	25.84	6.20	5.99	6.09
S.E. m (d) ±		0.06	0.06	0.04	0.40	0.32	0.26	0.73	0.80	0.54	0.20	0.30	0.18
C.D. (at 5%)		0.16	0.18	0.12	1.11	0.89	0.71	2.03	2.22	1.51	0.56	0.83	0.50
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Relative growth rate (RGR) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		RGR (mg/g/days) at											
		30 DAS			60 DAS			90 DAS			Harvest		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	6.78	6.90	6.84	42.93	42.90	42.92	21.07	21.02	21.04	3.30	3.18	3.24
MP 4010	V_2	7.07	6.93	7.00	43.60	43.57	43.58	20.91	21.09	21.00	3.45	3.48	3.47
S.E. m (d) ±		0.15	0.17	0.11	0.32	0.29	0.22	0.29	0.32	0.21	0.07	0.09	0.08
C.D. (at 5%)		NS	NS	NS	NS	NS	0.60	NS	NS	NS	NS	0.26	0.17
Seed rates													
100 kg/ha	S_1	7.06	6.99	7.03	43.43	43.72	43.58	22.14	21.97	22.05	3.37	3.37	3.37
125 kg/ha	S_2	6.98	7.04	7.01	44.05	43.92	43.98	20.36	20.34	20.35	3.43	3.47	3.45
150 kg/ha	S_3	6.73	6.71	6.72	42.31	42.06	42.19	20.46	20.85	20.65	3.32	3.15	3.24
S.E. m (d) ±		0.18	0.20	0.14	0.39	0.36	0.27	0.35	0.39	0.26	0.09	0.12	0.07
C.D. (at 5%)		NS	NS	NS	1.08	1.00	0.74	NS	NS	NS	NS	NS	NS
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	5.83	6.07	5.95	40.94	41.22	41.08	20.37	20.01	20.19	3.52	3.35	3.44
75% RDF + 5 tonnes FYM /ha	F_2	7.55	7.90	7.73	45.38	45.16	45.27	22.28	22.23	22.26	3.25	3.32	3.29
100% RDF	F_3	6.63	6.12	6.37	41.82	42.16	41.99	21.01	20.85	20.93	3.33	3.41	3.37
125% RDF	F_4	7.10	7.21	7.16	45.15	44.62	44.88	20.92	21.43	21.17	3.30	3.21	3.25
150% RDF	F_5	7.52	7.26	7.39	43.04	43.02	43.03	20.36	20.74	20.55	3.48	3.36	3.42
S.E. m (d) ±		0.23	0.26	0.18	0.50	0.47	0.34	0.46	0.50	0.34	0.12	0.15	0.09
C.D. (at 5%)		0.64	0.73	0.49	1.39	1.29	0.95	1.26	1.39	0.94	NS	NS	NS
Interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S

Table 7: Absolute growth rate (AGR) of wheat as influenced by varieties, seed rates and fertility levels at successive crop growth stages

Treatments		AGR (mg/days) at											
		30 DAS			60 DAS			90 DAS			Harvest		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	40.87	41.03	40.95	107.84	107.94	107.89	131.21	131.35	131.28	29.36	28.35	28.86
MP 4010	V_2	41.23	41.06	41.14	111.71	111.07	111.39	134.17	135.21	134.69	31.31	31.53	31.42
S.E. m (d) ±		0.18	0.20	0.14	1.28	1.02	0.82	2.32	2.54	1.72	0.71	1.05	0.64
C.D. (at 5%)		NS	NS	NS	3.54	2.82	2.26	NS	NS	NS	NS	2.92	1.76
Seed rates													
100 kg/ha	S_1	41.22	41.14	41.18	110.92	111.94	111.43	143.78	143.39	143.58	31.72	31.51	31.61
125 kg/ha	S_2	41.12	41.20	41.16	113.43	112.91	113.17	130.62	130.67	130.64	31.01	31.08	31.04
150 kg/ha	S_3	40.81	40.79	40.80	104.97	103.66	104.31	123.67	125.78	124.72	28.28	27.24	27.76
S.E. m (d) ±		0.22	0.25	0.17	1.56	1.25	1.00	2.84	3.11	2.10	0.87	1.29	0.78
C.D. (at 5%)		NS	NS	NS	4.33	3.46	2.77	7.87	8.61	5.83	2.42	3.58	2.16
Fertility levels													
50% RDF + 10 tonnes FYM /ha	F_1	39.72	40.02	39.87	96.04	97.87	96.95	114.43	113.59	114.01	28.28	27.01	27.64
75% RDF + 5 tonnes FYM /ha	F_2	41.81	42.26	42.04	121.52	121.63	121.57	155.48	155.74	155.61	32.83	33.73	33.28
100% RDF	F_3	40.69	40.07	40.38	102.15	102.02	102.08	125.31	123.83	124.57	28.28	28.71	28.50
125% RDF	F_4	41.26	41.41	41.33	118.78	116.59	117.69	140.02	142.98	141.50	31.31	30.32	30.82
150% RDF	F_5	41.78	41.46	41.62	110.39	109.41	109.90	128.20	130.24	129.22	30.98	29.93	30.45
S.E. m (d) ±		0.28	0.32	0.21	2.02	1.61	1.29	3.66	4.01	2.72	1.13	1.67	1.01
C.D. (at 5%)		0.78	0.89	0.59	5.59	4.46	3.58	10.16	11.11	7.53	3.16	NS	2.79
Interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 8: Interaction effect of varieties and seed rates on CGR of wheat

Treatments	CGR (g/m^2/days)	
	Varieties	
Seed rates	RVW 4106 (V_1)	MP 4010 (V_2)
100 kg/ha (S_1)	6.31	6.33
125kg/ha (S_2)	5.96	6.46
150 kg/ha (S_3)	5.04	6.06
S.E. m (d) ±	0.20	
C.D. (at 5%)	0.55	

Further, the NAR was maximum at early stages and decreased with advancement in crop growth and development. Since leaf area is taken in account while computing NAR, the leaf area steadily increased with crop growth and maximum in 75% RDF + 5 tonnes FYM/ha treated plots, thereby causing a mutual shading of leaves in the canopy leading to lower NAR values at later stages.

Nutrient Content and uptake

The study of the data on NPK content in wheat plant (Table 9 and 10) revealed that the NPK content affected significantly due to only fertility levels during both the years; however, varieties, seed rates and treatment interactions brought about non-significant influence in both the years as well as pooled basis.

Amongst fertility levels, significantly higher N content in wheat plant was recorded under treatment F_2 (75% RDF + 5 tonnes /ha) during both the years. The next effective treatment was F_5 (150% RDF) which was also found significantly higher over F_4, F_3 and F_1 during both the years. The minimum N content in was recorded under application of 50% RDF + 10 tonnes FYM /ha. Based on pooled data, crop fertilized with 75% RDF + 5 tonnes FYM /ha gave significantly higher N content (1.053%) compared other fertility levels. The lowest N content in recorded with application of 50% RDF + 10 tonnes FYM /ha, which was significantly lower as compared to other fertility treatments.

Amongst fertility levels, maximum P content in wheat plant was recorded under treatment F_2 (75% RDF + 5 tonnes FYM /ha) during both the years. However, it was found statistically at par with F_4 in 2013-14 and F_4 and F_5 in 2014-15. The minimum N content was recorded under application of 50% RDF + 10 tonnes FYM /ha, followed by 100% RDF and these both treatments were statistically at par with each other during both the years. Based on two years pooled data, significantly higher P content in wheat plant (0.160) was observed from the treatment F_2 (75% RDF+ 5 tonnes FYM /ha). The second best fertility was 125% RDF, which was statistically at par with 150% RDF and significantly superior over F_3 and F_1. Treatments F1 (50% RDF + 10 tonnes FYM/ha) gave the lowest P content in which was comparable to F_3.

Crop fertilized with 75% RDF+ 5 tonnes FYM resulted significantly higher K content in (1.169 and 1.178 in 2013-14 and 2014-15, respectively) as compared to other fertility levels except F_5 and F_4 during both the years of experimentation. The significantly lower K content in was recorded from F_1 (50% RDF + 10 tonnes FYM /ha) treatment, which was comparable with 100% RDF during both the years. Based on pooled data, crop fertilized with 75% RDF + 5 tonnes FYM /ha gave significantly higher K content in (1.174%) compared other fertility levels except F_5, However, treatment F_4 (125% RDF) was also gave significantly higher K content over remaining fertility levels. The lowest K content was recorded with application of 50% RDF + 50 tonnes FYM /ha, which was comparable to 100% RDF. Pandey *et al*. (1999) [7] also reported similar results on NPK content.

From the table no. 4.14 revealed that, Uptake of N by crop significantly influenced between varieties only on pooled basis data. Based on pooled data, higher N uptake (110.14 kg/ha) recorded with variety MP 4010. On the basis of two years pooled data, uptake of N by wheat crop observed in the range of 104.55 to 112.45 kg/ha under different seed rates. Application 150 kg/ha seed (S_3) showed maximum uptake of N, which was significantly higher than 100 kg/ha seed rate and at par with 125 kg/ha seed rate during both the years as well as on pooled basis. In case of fertility levels, the maximum uptake of N by crop was recorded with 75% RDF + 5 tonnes FYM /ha, which was significantly higher over other fertility levels during both the years. The next best treatment in respect of this parameter was 150% RDF, which was significantly superior over remaining fertility treatments. The minimum N uptake by crop was recorded from 50% RDF+ 10 tonnes FYM /ha whish was found inferior compared to all treatments fertility levels during both the years. Similar trend was observed on pooled basis data.

The data on P uptake by crop (Table 4.24) reveals that the uptake of P by crop was affected significantly due to different seed rates and fertility level for both the years as well as on pooled basis. However, the uptake of P between varieties was found to be significant only on pooled. Variety MP 4010 recorded significantly higher P uptake compared to RVW 4106.

Application of 150 kg/ha seed rate recorded maximum P uptake by crop as compared to seed rate 100 kg/ha during both the years. However, it was statistically identical to seed rate 125 kg/ha during both the years. The minimum values of P uptake by crop were noted with 100 kg /ha seed rate during both the years. Similar trends was noted on pooled data Amongst fertility levels, the maximum uptake of P by crop was recorded with 75% RDF + 5 tonnes FYM /ha, which was significantly higher over other fertility levels during both the years except F_4 in 2013-14 and F_5 in 2014-15. Minimum P uptake by crop was recorded from 50% RDF + 10 tonnes FYM /ha. Based on pooled basis data, significantly higher P uptake was also registered with treatment F_2 (75% RDF + 5 tonnes FYM /ha) followed by F_4 and F_5. Lowest P uptake (14.99 kg/ha) was recorded with application of 50% RDF + 10 tonnes FYM /ha.

Table no. 10 revealed that Potassium uptake did not differed significantly due to varietal treatments during both the years of experimentation. However, at pooled basis, it influenced significantly and recorded higher K uptake with variety MP 4010 as compared to variety RVW 4106. Amongst seed rates, Maximum K uptake by crop was registered with treatment S_3 (150 kg/ha seed rate) followed by S_2 (125 kg/ha seed rate) and both treatments were statistically at par with each other during both the years. Lowest K uptake was recorded under application of 100 kg /ha seed rate. Similarly, based on pooled data significantly higher K uptake was also obtained with 150 kg /ha seed rate over other treatments of seed rate. Minimum K uptake was found with 100 kg/ha seed rate. In case of fertility levels, the maximum uptake of K by crop was recorded with 75% RDF + 5 tonnes FYM t/ha, which was significantly higher over other fertility levels during both the years except F_5 and F_4 in 2013-14 and F_5 in 2014-15. Minimum K uptake was found with F_1 (50% RDF + 10 tones FYM/ha) treatment Almost similar trend was observed on pooled basis data. These results are in tune with Pandey *et al*. (2007) [8] who reported significant increase in N, P and K uptake with increased fertilizer levels. Das *et al*. (2012) [3] also reported that combination of FYM + NPK fertilizer improve NPK uptake compared to alone NPK fertilizer.

Table 9: Nitrogen, phosphorus and potassium content (%) in wheat as influenced by varieties, seed rates and fertility levels

Treatments		Nitrogen content (%)			Phosphorus content (%)			Potassium content (%)		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	0.969	0.967	0.968	0.151	0.151	0.151	1.096	1.101	1.098
MP 4010	V_2	0.978	0.975	0.976	0.153	0.153	0.153	1.115	1.117	1.116
S.E. m (d) ±		0.005	0.004	0.003	0.001	0.001	0.001	0.10	0.11	0.07
C.D. (at 5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Seed rates										
100 kg/ha	S_1	0.979	0.975	0.977	0.152	0.154	0.153	1.112	1.118	1.115
125 kg/ha	S_2	0.974	0.972	0.973	0.153	0.151	0.152	1.096	1.104	1.100
150 kg/ha	S_3	0.967	0.965	0.966	0.151	0.151	0.151	1.108	1.106	1.107
S.E. m (d) ±		0.006	0.005	0.004	0.001	0.001	0.001	0.012	0.013	0.009
C.D. (at 5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility levels										
50% RDF + 10 tonnes FYM /ha	F_1	0.873	0.869	0.871	0.145	0.143	0.144	1.017	1.025	1.021
75% RDF + 5 tonnes FYM /ha	F_2	1.056	1.050	1.053	0.159	0.160	0.160	1.169	1.178	1.174

100% RDF	F_3	0.932	0.933	0.932	0.146	0.146	0.146	1.051	1.047	1.049
125% RDF	F_4	0.981	0.981	0.981	0.157	0.155	0.156	1.137	1.141	1.139
150% RDF	F_5	1.024	1.021	1.023	0.153	0.155	0.154	1.152	1.156	1.154
S.E. m (d) ±		0.007	0.007	0.005	0.002	0.002	0.001	0.15	0.17	0.11
C.D. (at 5%)		0.020	0.018	0.014	0.004	0.005	0.003	0.42	0.46	0.31
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 10: Effect of different varieties, seed rates and fertility levels on nitrogen, phosphorus and potassium uptake (kg/ha) by wheat

Treatments		**Uptake of nutrients**								
		Nitrogen uptake (kg/ha)			**Phosphorus uptake (kg/ha)**			**Potassium uptake (kg/ha)**		
Varieties	**Sy.**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
RVW 4106	V_1	108.45	108.30	108.37	16.93	16.86	16.89	122.63	123.32	122.97
MP 4010	V_2	110.48	109.79	110.14	17.26	17.24	17.25	125.95	125.80	125.88
S.E. m (d) ±		0.74	0.66	0.50	0.14	0.15	0.10	1.25	1.32	0.91
C.D. (at 5%)		NS	NS	1.38	NS	NS	0.29	NS	NS	2.52
Seed rates										
100 kg/ha	S_1	104.95	104.14	104.55	16.29	16.41	16.35	119.12	119.35	119.24
125 kg/ha	S_2	111.15	110.39	110.77	17.40	17.12	17.26	125.01	125.26	125.13
150 kg/ha	S_3	112.30	112.60	112.45	17.59	17.62	17.61	128.75	129.06	128.90
S.E. m (d) ±		0.91	0.81	0.61	0.17	0.19	0.13	1.53	1.62	1.11
C.D. (at 5%)		2.53	2.23	1.69	0.47	0.52	0.35	4.25	4.48	3.09
Fertility levels										
50% RDF + 10 tonnes FYM /ha	F_1	90.82	90.46	90.64	15.07	14.91	14.99	105.89	106.66	106.27
75% RDF + 5 tonnes FYM /ha	F_2	122.50	121.35	121.92	18.49	18.51	18.50	135.63	136.20	135.91
100% RDF	F_3	103.34	103.26	103.30	16.22	16.19	16.20	116.49	115.88	116.19
125% RDF	F_4	112.39	111.78	112.08	18.02	17.69	17.85	130.41	129.99	130.20
150% RDF	F_5	118.28	118.38	118.33	17.67	17.94	17.81	133.04	134.06	133.55
S.E. m (d) ±		1.18	1.04	0.79	0.22	0.24	0.16	1.98	2.09	1.44
C.D. (at 5%)		3.26	2.88	2.18	0.60	0.67	0.45	5.48	5.78	3.98
interaction		NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

On the basis of results obtained from this study, it can be concluded that the cultivation of wheat variety MP 4010 in late sown condition, when sown with the seed rate of 150 kg/ha and provided 75% of RDF along with 5 tonnes FYM /ha were found most suitable as compared to other treatments for achieving the physiological parameter, nutrient content and uptake of wheat crop.

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