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RESEARCH PAPER

Studies on agro-chemicals for lodging management in wheat (*Triticum aestivum* L.) for higher productivity

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Aberrant weather conditions prevailing in the last few years increased the threat of wheat lodging which is a limiting factor for higher productivity and thus, lodging management is very important to sustain and achieve higher wheat yields. Keeping this in view, two studies were conducted to manage lodging in wheat by evaluating agro- chemicals. Experiment I consisted of 12 treatments laid in Factorial Randomized Block Design with three replications having four NPK doses and three growth regulators, NGR, GR1 and GR2. Results revealed that RDF resulted in more tiller/m^2, shoot: emergence ratio, increased plant height, increased dry matter but these growth parameters were at par with SSNM-7 and SSNM-8. RDF resulted in minimum lodging angle, area lodged per cent and lodging score, highest grain yield and highest harvest index, maximum gross return, net returns and B: C , maximum nitrogen and phosphorus uptake by grain. Whereas potassium uptake was highest under SSNM-8. Nutrient doses above RDF favoured the wheat lodging. GR2 resulted in higher emergence, higher tiller/m^2, lower mortality percentage, higher dry matter production, higher leaf area index, higher 1000 grain weight. However, plant height and internode length was minimum in GR1.Grain yield and harvest index was higher in GR1. Interaction effects for lodging observation revealed that RDF with GR1 resulted in lower lodging angle, area per cent lodged and lodging score. RDF with GR2 resulted in higher 1000 grain weight. Grain yield and harvest index was highest in RDF with GR1. In experiment-2 lodging was induced manually at grain filling stage by dragging a rope over plot to evaluate the effect of agro-chemicals on recovery ability of induced lodged wheat. This experiment consisted of five treatments as RDF+WL, RDF+IL, RDF+IL+ ethrel, RDF+IL+KC1 and RDF+IL+nano-silicon. Results revealed that tiller/m^2, shoot: emergence ratio, plant height was not affected by treatments. Dry matter, leaf area index, peduncle length, internode length, days taken to physiological maturity was highest in RDF+WL. Lodging angle, area per cent lodged and lodging score was minimum in RDF + nano-silicon. 1000 grain weight was maximum in RDF+WL which was at par with RDF+IL+ nano-silicon. Grain yield, biological yield, straw yield and harvest index was highest in RDF+WL. Gross return, net return, benefit: cost ratio was highest in RDF+WL. Ethrel, KC1 and nano- silicon have recovered the wheat from induced lodging, but nano-silicon was more effective in recovering from artificially induced lodging. However, these chemicals did not recover the crop fully and yield was still much lower than RDF + WL. From this study it can be concluded that RDF along with cycocel should be recommended for wheat crop to minimize the crop lodging and thus, produce more grain yield.

Key words : NPK, SSNM-7, SSNM-8, Nano-silicon, NGR

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INTRODUCTION

Lodging is a major limiting factor for many crops at global level, especially under excessive irrigated conditions or where rainfall and high winds are common lodging severely affects the yield and yield losses vary depending upon the intensity of lodging and stage at which lodging occurs. Lodging reduces the yield in cereals and oilseeds which ranges from 25 per cent, upto 75 per cent depending upon the stage of crop at which lodging occurs (Berry and Spink, 2012 and Berry, 2013). Lodging results in poor grain filling, reduces the grain quality, interferes with nutrient uptake and reduces mechanical harvesting efficiency (Acreche and Slafer, 2011). In India about 8.3 per cent yield losses in wheat occur due to lodging and 5 per cent losses in maize. In UK on an average 15-20 per cent area under wheat gets lodged every 3 or 4 years. In India about 6.3 mha areas under wheat crop in 2015 suffered significantly due to crop lodging and damage across major wheat growing belts due to rains, strong wind and hailstorms.Among yield contributing parameters; genetic potential, proper land preparation, proper and judicious use of fertilizers, use of good quality seed, optimum seed rate, timely cultural operations and plant protection measures determine the yield. In recent years, however, lodging is reported to be one of the most limiting factors in attaining higher wheat yields under intense cultivation practices. Lodging resistance is considered one of the highest priorities for plant breeders worldwide (Reynolds and Borlaug, 2006). Lodging is a complicated phenomenon which is influenced by many environmental factors like wind, rainfall, topography, soil type, previous crop management and diseases. Besides these factors, many morphological and anatomical plant traits like plant height, internode length, stem thickness, wall thickness as well as breaking strength, plant density, culm anatomy and chemical compositions of stem and root characters, head density and size. Lodging can be managed by various agronomic practices like optimum seed rate, balanced fertilizer dose, proper irrigation, method of sowing, blending of varieties of different height and management of weeds, insects and diseases. In the Indian sub-continent, lodging occurs when fertilizer rates are increased from 120kg N/ha. Stem lodging generally occurs 2-3 months prior to harvesting of crop. Plant height, especially culm length, is considered to be one of the major factors associated with lodging sensitivity. So crop lodging can be effectively managed by manipulating the plant height. Potential use of plant growth regulators and related compounds minimize the lodging as they reduce the plant height. The synthetic plant growth regulators such as chlormequat chloride ethephon, trinexepac-ethyl and prohexadione-calcium can minimize lodging risk by reducing stem elongation. Chlormequat and ethephon are the common plant growth regulators which are often used to limit lodging in wheat, hence, allowing cultivation of lodging susceptible, adapted, high yielding cultivars under higher input use. Various techniques have been used by different workers to study and determine the effects of artificial lodging in wheat. However, little study has been done to determine the recovery ability of wheat after lodging. Different agro-chemicals like potassium, silicon may help in recovery of wheat from lodging and make the leaves erect. Potassium application increases the thickness of sclerenchyma tissue layers in rice increases the lodging resistance of maize stalks and decreases the percentage of senescent stalks. Silicon deposition in culm and leaves increases mechanical strength and thus, improve light distribution in canopy and improved plant height, inter-node length, fresh weight, bending moment, breaking resistance, lodging index and increases lodging resistance in rice (Fallah, 2008). Disease infestation besides weak culms, genetic traits or insect attack also contributes stem lodging in wheat. Thus, fungicides are applied to avoid disease related yield losses and enhance grain yields by simply prolonging grain filling period and increasing kernel weights. In the U.S., various reports have shown yield increases in winter wheat after the fungicide application. Wegulo *et al.* (2009) showed that upto 42 per cent yield loss was prevented by fungicide application in wheat. Mineral nutrition also plays an important role in cereal lodging especially nitrogen nutrition. Higher doses of nitrogen have been reported to increase lodging due to increased plant height, increased lower internode length, reduced development of secondary roots and increased shoot: root ratio (Rajkumara, 2008). Wheat requirements are rapidly increasing every year because of increasing population. According to FAO (2009), by 2050 annual production of wheat in world will rise to 840 million tonnes from current requirement which is about 642 million tonnes. Similarly, wheat requirement in India has to be increased to 140 million tonnes by 2050. Since there are considerable yield gaps in our country among major wheat producing states. Considerable yield gaps also exist between researchers managed optimum NPK plots and farmers' fertilizer practices indicating a great opportunity for enhancing wheat productivity by proper nutrient management practices. Nutrient recommendations in our country are generally based upon crop response data averaged over large geographic areas and these recommendations do consider the spatial variability in indigenous nutrient supplying capacity of soils (Majumdar *et al.,* 2013). Therefore, blanket fertilizer application results in both over and under fertilizations in some or in other cases. Surveys in the Indo-Gangetic Plains revealed that farmers generally apply higher doses of nitrogen and phosphorus but ignore the sufficient application of potassium and other secondary and micro-nutrients. Hence, there is a need to optimize the fertilizer dose and to overcome the problems of imbalanced fertilizer application in wheat, a recently developed decision support systems. Nutrient expert synthesizes the on-farm research data into a simple delivery system that enables farmers to rapidly implement SSNM for their individual fields. The SSNM-NE software tool is developed by International Plant Nutrition Institute in collaboration with International Maize and Wheat Improvement Centre (Satyanarayana *et al.*, 2013). Nutrient expert is basically a decision support tool developed for maize and wheat crops and is based on SSNM principles. It is computer based decision support system, easy-to-use, quite interactive and rapidly provides nutrient recommendations for an individual farmer field both in the presence and absence of soil-testing data and hence, provides fertilizer recommendations for a specific conditions. In short, this tool estimates the yield that can be attained in a farmer's field based on the growing conditions, estimates the nutrient balance in the cropping system based on yield and fertilizer/manure applied in the previous crop and at last combines all information with soil characteristics to predict expected N, P and K response in the concerned field to generate a location specific nutrient recommendation for wheat crop. Wheat known as the "king of cereals" is one of the most important cereal crops and is next to rice in India and meets about 61 per cent of the protein requirement of the country's people. Wheat production was 90.8mt which is about 35 per cent of cereal food production of country and area under wheat cultivation was 31 5 mha which is 24 per cent of total area under food grains (Majumdar *et al.*, 2013). India contributes 13.2 per cent in global wheat production.This research was, therefore, conducted to determine how different fertilizers regimes, different growth regulators effect the lodging incidence and subsequent yield expression, recovery ability of wheat under artificially induced conditions, to understand better interactive effect of these factors to provide better alternative management practices to farmers facing chronic problem of crop lodging.

RESEARCH METHODOLOGY

Experiment details, materials used, procedure followed and technique adopted during the course of investigation are described in this chapter.

Seedbed preparation and sowing:

The field was prepared by the deep ploughing by using the tractor drawn soil turning plough followed by two cross harrowing and leveling. Deep furrow of 4-5cm depth was opened through the furrow opener at the spacing of 20cm and the seeds were manually placed in the furrow uniformly and covered by the soil immediately.

Irrigation:

Irrigation was given at 4 stages at critical root initiation stage, jointing stage, flowering and milking stage.

Weeding:

For controlling the weed, pendimethalin @ 1.0kg per hectare as pre-emergence herbicide and in later growing period weeds were controlled by hand weeding.

Harvesting and threshing:

The maturity of the crop was determined visually when all the leaves dried and the peduncle turn into golden yellow and the grains dried to ripe. Net plots were harvested manually and total biological yield was calculated by weighing the biomass of each plot with the help of balance. Threshing was done with thresher. The grains were collected separately in the cloth bags during the threshing and then weighed and finally calculated as hectare basis.

Observations:

For observations, the sampling area was demarked in each plot. One row from the both side of the plot was used as a border row and second row in both sides were taken as sampling area. The following observations were recorded from the sampling area.

Plant height:

The height of ten randomly selected plants within one metre row length was measured with a metre scale from the base of the plant to the top of the tallest leaf before emergence of spike and from ground level to the tip of spike after the emergence of spike. The mean of ten plants was recorded as height (cm) of plant at 30, 60, 90 and 120 DAS and at harvesting.

Tillers/m^2:

Total number of tillers was counted from observation area of one metre row length of crop in the second row leaving 50cm in the beginning of each plot for recording observation and expressed as tillers per metre square. Tiller/m^2 was recorded at 30, 60, 90,120DAS.

Shoot:

Emergence ratio and mortality percentage:

Emergence ratio was determined at 30, 60, 90,120 DAS and at harvesting. It was calculated by counting the corresponding shoot per square meter at 30, 60, 90, 120 DAS and at harvesting and then dividing the shoots by number of emerged plants. Mortality percentage with respect to 60DAS was determined at 90,120DAS and at harvesting by the formula:

$$\textbf{Mortality \%} = \frac{\textbf{Slloots at 60 DAS} - \textbf{Stioots at 90 DAS}}{\textbf{Slloots at 60 DAS}} \textbf{x100}$$

Internode length:

Internode length (cm) was measured at 90 and 120 DAS. 1st internode and 2nd internode was measured. 1st internode means the top most internode and 2nd means the just lower the top most. Internode length of five randomly selected plants was measured from each plot and then it was reported at internode length per plant (cm).

Dry matter accumulation:

Plants from each plot were cut closely to the ground in 25cm row length from 2nd row at 30, 60, 90 and 120 days after sowing. The samples were dried at 70°C for 48hrs and weighed. The dry matter accumulation was expressed in g per square metre.

Phonological indices:

Days taken to 50 per cent heading:

A regular counting of emerged heads at two days interval were made from 1 metre earmarked rows just after commencing of heading and continued till full heading of crop. By calculating the number of 50 per cent heads on the basis of the total heads, respective days will be calculated. The number of days from sowing to the date of completing 50 per cent heading reported as days taken to 50 per cent heading.

Days taken to anthesis:

A regular counting of emerged heads at two days interval were made from 1metre earmarked rows just after commencing of anthesis and continued till full anthesis of crop. By calculating the number of 50 per cent anthesis on the basis of the total heads, respective days will be calculated. The number of days from sowing to the date of completing 50 per cent anthesis reported as days taken to 50 per cent anthesis.

Days taken to maturity:

The numbers of days were taken from the sowing to stage when all the leaves dried and the peduncle turn into golden yellow and the grains dried to ripe.

Post harvest studies:

Ten spikes were harvested randomly at time of maturity for recording yield attributes.

Spikes per square metre:

Spikes were counted from two metre row length and reported on the basis of number of spikes per square metre.

Spike length:

Spike length was measured from its base to the tip, excluding awns and was expressed in centimeter.

Peduncle length:

Peduncle length was measure from base of the spike to last internodes.

Fertile spikelets per spike:

Spikelets bearing grains were counted from ten selected spikes and average of them was taken as fertile spikelets per spike.

Sterile spikelets per spike:

Spikelets having no grains were counted from ten selected spikes and average of them was as sterile spikelets per spike.

Grains per spike:

All the ten selected spikes were threshed and total obtained grains were counted. The average of them was calculated to find out the grains/spike.

Grain weight per spike:

The total obtained grains from ten spikes were weighed; average was worked out and reported as grain weight/spike.

1000 grain weight:

One thousand grains from net plot area were counted and weighed to get 1000 grains weight (g).

Grain yield:

Grain yield was recorded from the net plot area after threshing and cleaning. Initially it was recorded in kg per plot and then calculated as quintals per hectare.

Straw yield:

Straw yield per plot was obtained by subtracting the grain yield from that of the total biomass produced per plot, recorded in kg per plot and reported as quintals per hectare.

Biological yield:

Biological yield was calculated by adding the grain and straw yield per plot and reported as quintals per hectare.

Plant nutrient studies:

Nitrogen concentration and uptake:

Composite plant samples (grain and straw) were taken from each treatment at harvest then materials were oven dried (70±1°C for 72 hrs.) and grind separately, Nitrogen content in these plant was determined by Micro-Kjeldhahl's method and the total nitrogen uptake was calculated by multiplying nitrogen concentration into the total grain and straw yield.

Phosphorus concentration and uptake:

Plant samples were taken from the composite plant samples. Vanado-molybdo- phosphoric acid yellow colour were used to estimation phosphorus was calculated.

Potassium concentration and uptake:

Plants samples were analyse for potassium concentration (%) with the help of flame photometer and total potassium uptake by grain and straw was worked out separately.

Economics analysis:

Cost of cultivation by using various treatment combinations was worked out separately. The labour needs and mechanical powers for different operation such as land preparation, sowing, fertilizer application, harvesting and threshing etc. were calculated as per government rules.

Gross return:

Gross return worked out on the basis of current minimum support price prevailing during the financial year 2016-17.

Net return:

Net return was calculated by deducing cost of cultivation from the gross return.

Benefit cost ratio (B:C ratio):

B:C ratio was calculated by dividing the net return by the cost of cultivation in particular treatment.

RESEARCH FINDINGS AND ANALYSIS

Data recorded during the study are presented in form of tables and explained through figures and facts.

Growth studies:

Experiment-1: *Effect of NPK doses and growth regulators on lodging management in wheat* :

Emergence counts:

Crop emergence was counted after 10 days of

Table 1: Emergence influenced by the different NPK doses and growth regulators

Treatments	Emergence/m^2
NPK dose	
Absolute control	164
RDF	178
SSNM-7	185
SSNM -8	207
S.E.±	5.97
C.D. (P=0.05)	17.5
Growth regulator	
NGR	180
GR1	194
GR2	177
S.E. ±	5.13
C.D. (P=0.05)	NS
C.V. (%)	10.12
Interaction	NS

NS= Non-significant

sowing and data are presented in Table 1. Emergence counts were found significant due to NPK doses but were non-significant due to the growth regulators. Among NPK doses maximum emergence was found under SSNM-8 which was significantly higher than the other treatments. This may be due to the reason that higher doses of nutrients were applied at basal which initially provides a bunch of energy to the plumule to crack the soil surface.

Tillers:

Tillers per square meter were recorded at 30, 60, 90 and 120 days after sowing and are presented in Table 2. Tillers were increased upto 60 days after sowing, thereafter, decreased with advancement of the crop stage, irrespective of NPK doses and growth regulators. Tillers per meter square were significantly affected by NPK doses at all growth stages. At 30DAS, SSNM-8 gave maximum number of tillers which was at par with RDF and SSNM-7 but was significantly higher than absolute control. At 60DAS, maximum tillers per square meter were recorded under SSNM-8 which was significantly higher than all other treatments. At 90DAS, maximum tillers per square meter were observed under SSNM-7 which was at par with other treatments except absolute control. At 120DAS, maximum tiller was recorded under SSNM-8 which was at par with the other treatments except to absolute control. Growth regulators failed to give significant effect on tillers/m^2 except at 120DAS. At 120DAS, maximum number of tillers was found under GR2 treatment which was significantly higher than GR1 and NGR.

Table 2: Tillers per square meter influenced by NPK doses and growth regulators

Treatments	Tillers/m^2			
	30 DAS	60 DAS	90 DAS	120 DAS
NPK dose				
Absolute control	353	467	320	267
RDF	450	627	450	398
SSNM-7	449	634	486	402
SSNM -8	416	693	484	404
S.E.±	16.5	15.6	12.0	10.0
C.D. (P=0.05)	48	46	36	29
Growth regulator				
NGR	439	597	426	358
GR1	411	624	428	357
GR2	400	595	449	387
S.E.±	14.3	13.5	10.4	8.6
C.D. (P=0.05)	NS	NS	NS	25
C.V. (%)	11.88	7.72	8.29	8.15
Interaction	NS	NS	NS	NS

NS= Non-significant

Table 3: Shoot emergence ratio and mortality per cent as effected by NPK doses and growth regulators

Treatments	Shoot emergence ratio					Mortality % as compared to 60DAS		
	30 DAS	60 DAS	90 DAS	120 DAS	Harvesting	90 DAS	120 DAS	Harvesting
NPK dose								
Absolute control	2.2	2.9	2.0	1.7	0.3	30.9	42.6	55.0
RDF	2.3	3.2	2.8	2.4	0.7	28.2	36.1	47.2
SSNM-7	2.8	4.0	3.0	2.6	2.2	23.2	36.2	44.2
SSNM -8	2.5	4.1	2.9	2.8	2.0	29.7	41.2	49.8
S.E.±	0.11	0.13	0.12	0.11	0.1	2.7	2.53	2.7
C.D. (P=0.05)	0.3	0.4	0.3	0.3	0.3	NS	NS	6.7
Growth regulator								
NGR	2.4	3.3	2.4	2.0	1.7	28.5	39.4	50.0
GR1	2.3	3.5	2.4	2.0	1.7	31.0	42.4	50.9
GR2	2.6	3.9	3.0	2.6	2.1	24.5	35.0	46.3
S.E.±	0.10	0.11	0.12	0.09	0.08	2.34	2.19	2.0
C.D. (P=0.05)	0.3	0.3	0.3	0.3	0.2	NS	NS	NS
C.V. (%)	14.38	11.36	14.18	15.33	15.2	29.05	19.5	13.9
Interaction	0.6	0.7	0.6	0.6	0.5	NS	NS	NS

NS= Non-significant

Shoot:

Emergence ratio and tiller mortality percentage:

Emergence ratio was calculated at 30, 60, 90,120 DAS and at harvesting .The data are given in Table 3. Highest shoot: Emergence ratio was found at 60DAS and thereafter, it decreased with the advancement of crop stage. Shoot emergence ratio was significantly affected by NPK doses and growth regulators. Among NPK doses SSNM-7 produced maximum shoot per emerged plant at all growth stages, which was at par with SSNM-8 and significantly higher than the other treatments. Among growth regulators, GR2 significantly gave higher shoot emergence ratio as compared to GR1 and absolute control at all growth stages. Interaction effects between NPK doses and growth regulators on shoot emergence ratio was found significant at all growth stages, but here we are discussing interaction effects at harvesting only. SSNM-7 along with GR2 produced maximum shoot per emerged plant which was significantly higher to other treatments except to SSNM-7 with GR1 and SSNM-8 with GR2. At SSNM-7, GR1 and GR2 had produced significantly higher shoot per emerged plant compared to NGR. However, at SSNM-8 only GR2 had significant effect on shoot emergence ratio over GR1 and absolute control. NPK doses failed to give any significant effect on mortality percentage except at harvesting. At harvesting, among NPK doses absolute control significantly gave higher mortality percentage than the other treatments whereas SSNM-7 resulted in lowest mortality percentage which was at par with RDF and SSNM-8. Mortality percentage among growth regulators was non-significant at all growth stages.

Table 4 : Interaction effects of NPK doses and growth regulators on shoot emergence ratio at harvesting

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	1.5	1.1	1.2
RDF	1.5	1.5	2.1
SSNM-7	1.7	2.3	2.6
SSNM -8	1.8	1.9	2.5
S.E.±	0.2	-----	------
C.D. (P=0.05)	0.5	------	----

Plant height:

Plant height was recorded at 30,60, 90 and 120 days after sowing and at maturity. The data are given in Table 5. Plant height was affected significantly due to NPK doses at all growth stages. Plant height was significantly affected by growth regulator at all growth stages except at 30 DAS. Among NPK doses all treatments significantly enhanced the plant height over absolute control at all growth stages. At 30 DAS, plant height was highest in SSNM- 7 at all growth stages but was at par with

Table 5 : Plant height influenced by NPK doses and growth regulators

Treatments	Plant height (cm)				
	30DAS	60DAS	90DAS	120DAS	Maturity
NPK dose					
Absolute control	27.6	44.2	76.1	94.2	93.8
RDF	29.8	53.1	85.6	103.2	101.4
SSNM-7	32.3	55.5	90.3	105.6	103.5
SSNM -8	32.0	55.1	91.4	105.8	103.8
S.E.±	0.64	1.10	1.27	0.74	1.18
C.D. (P=0.05)	1.9	3.7	3.74	2.1	3.4
Growth regulator					
NGR	30.3	53.9	85.8	103.6	101.3
GR1	30.6	49.4	81.7	98.3	95.6
GR2	30.4	48.4	80.4	97.7	96.4
S.E.±	0.56	1.10	1.10	0.64	1.02
C.D. (P=0.05)	NS	3.2	3.24	1.9	3.0
C.V. (%)	6.41	7.56	4.63	2.24	3.75
Interaction	NS	NS	NS	NS	NS

NS= Non-significant

SSNM- 8. At 60DAS, SSNM- 7 resulted in highest plant height which was at par with all treatment except to absolute control. At 90DAS, plant height was maximum under SSNM-8 but was significantly higher to all other treatments except SSNM-7. At 120 DAS plant height was highest in SSNM-8 but it remained at par with SSNM-7. At maturity plant height was maximum in SSNM-8 but it remained at par with SSNM-7 and RDF. Among growth regulators, GR1 and GR2 significantly reduced the plant height as compared to NGR at all growth stages. At maturity plant height by GR1 and GR2 was reduced by 6 and 4.9cm, respectively as compared to NGR.

Dry matter accumulation:

The data related to dry matter accumulation are given in Table 6. Dry matter accumulation was affected significantly by NPK doses at all growth stages but was not significantly affected by growth regulators. The interaction effects between NPK doses and growth regulator on dry matter accumulation was found non-significant at all growth stages. SSNM-8 produced significantly higher dry matter as compared to absolute control and RDF, but was at par with SSNM-7, at all growth stages except at 120DAS. However, at 120DAS, SSNM-8 produced dry matter that was at par with all treatments except to absolute control. This might be due to fact that higher doses of nutrients particularly nitrogen resulted in increased plant height, higher tillers/m^2 that resulted in more photosynthesis and hence, more dry matter accumulation.

Table 6: Dry matter accumulation as effected by NPK doses and growth regulators

Treatments	Dry matter (g/m^2)			
	30DAS	60DAS	90DAS	120DAS
NPK dose				
Absolute control	63.0	300.6	492.1	1023.4
RDF	86.4	485.2	804.9	1651.6
SSNM-7	92.6	541.1	880.4	1717.5
SSNM -8	93.1	587.8	884.0	1728.7
S.E.±	3.98	19.76	21.39	42.25
C.D. (P=0.05)	11.6	58.06	62.7	123.9
Growth regulator				
NGR	86.1	502.1	782.3	1560.5
GR1	81.6	484.0	736.3	1461.9
GR2	79.1	449.9	777.6	1568.5
S.E.±	3.44	17.14	18.52	36.59
C.D. (P=0.05)	NS	NS	NS	NS
C.V. (%)	14.52	12.4	8.38	8.28
Interaction	NS	NS	NS	NS

NS= Non-significant

Leaf area index:

NPK doses had significant effect on LAI, but growth regulator failed to give significant effect on LAI. Leaf area index was increased with increase in the NPK (Table 7). At 30DAS, LAI was highest under SSNM-7 which was at par with all treatments except to absolute control. At 60 DAS, LAI was recorded maximum in SSNM-8, which was at par with SSNM-7 but significantly higher as compared to RDF and absolute control. At 90 DAS, SSNM-7 resulted in maximum LAI, which remained at par with SSNM-8 but was significantly higher as compared to RDF and absolute control. At 120 DAS, LAI was maximum in SSNM-8 which was at par with all treatments except to absolute control. The increase in leaf area index with higher nitrogen doses is due to more plant height, number of tillers which resulted in more ground surface coverage.

Table 7: Leaf area index influenced by NPK doses and growth regulators

Treatments	Leaf area index			
	30DAS	60DAS	90DAS	120DAS
NPK dose				
Absolute control	0.98	1.95	2.36	2.42
RDF	1.34	3.15	3.67	4.01
SSNM-7	1.44	3.51	4.25	4.22
SSNM -8	1.33	3.82	4.21	4.24
S.E.±	0.06	0.12	0.10	0.40
C.D. (P=0.05)	0.18	0.37	0.30	0.30
Growth regulator				
NGR	1.33	3.26	3.7	3.74
GR1	1.26	3.14	3.5	3.55
GR2	1.22	2.92	3.6	3.81
S.E.±	0.05	0.11	0.09	0.09
C.D. (P=0.05)	NS	NS	NS	NS
C.V. (%)	14.59	12.4	8.66	8.44
Interaction	NS	NS	NS	NS

NS= Non-significant

Peduncle length and internode length:

Data related to peduncle length are shown in Table 8. NPK doses failed to affect the peduncle length but growth regulators gave significant effect on peduncle length. Reduction in peduncle length was noticed due to growth regulator. Peduncle length in GR2 was at par with GR1 but significantly lower than NGR. Interaction between NPK doses and growth regulator on peduncle length was non-significant. Internode length 1st and 2nd was found significantly affected by NPK doses as well at growth regulators at 90 and 120DAS. It was observed that NPK doses resulted in increase in internode length. Among NPK doses, 1st and 2nd internode length was maximum under SSNM-8 which was significantly higher than absolute control but remained at par with RDF and SSNM-7. Among growth regulators, GR1 significantly reduce the Pt internode length at 90 and 120DAS as compared to GR2 and NGR. 2nd internode length at 90DAS was significantly lower in GR1. However, at 120DAS, 2nd internode length at GR1 was at par with GR2 but significantly lower than NGR. At all growth stages 1st internode length was highest in NGR which was significantly higher than GR1 and GR2.

Table 8: Peduncle length and internode length as affected by treatments

Treatments	Peduncle length (cm)	1st internode length (cm)		2nd internode length (cm)	
		90DAS	120DAS	90DAS	120DAS
NPK dose					
Absolute control	29.3	25.7	29.3	11.0	14.1
RDF	30.8	30.6	33.0	11.7	15.7
SSNM-7	30.7	29.8	33.2	12.8	16.5
SSNM -8	29.8	30.8	33.6	13.1	16.7
S.E.±	0.69	0.52	0.58	0.50	0.42
C.D. (P=0.05)	NS	1.52	1.71	1.49	1.23
Growth regulator					
NGR	32.6	30.0	33.9	13.3	17.0
GR1	28.8	27.7	30.9	10.5	14.6
GR2	28.9	29.8	32.0	13.0	15.7
S.E. ±	0.60	0.45	0.50	0.44	0.36
C.D. (P=0.05)	1.76	1.32	1.48	1.29	1.07
C.V. (%)	6.92	5.36	5.42	12.41	8.04
Interaction	NS	NS	NS	NS	NS

NS= Non-significant

Lodging observations:

Data are shown in Table 9. Lodging angle was significantly affected by NPK doses and growth regulators. Lodging observations were recorded at harvesting time. Among NPK doses, maximum lodging angle was found in SSNM- 8 which was at par with SSNM-7 and minimum angle was under absolute control and recommended NPK. The reason may be that higher doses of nutrient especially nitrogen resulted in weak, tall stem having less strength that increased the lodging

Table 9: Lodging angle, area lodged (%) and lodging angle as affected by NPK doses and growth regulators

Treatments	Lodging angle (°)	Area lodged (%)	Lodging score
NPK dose			
Absolute control	0.0	0.0	0.0
RDF	0.0	0.0	0.0
SSNM-7	40.0	23.9	11.3
SSNM -8	43.0	30.0	15.1
S.E.±	2.11	1.31	0.621
C.D. (P=0.05)	6.2	3.86	1.82
Growth regulator			
NGR	25.0	22.9	12.6
GR1	18.8	5.8	2.4
GR2	18.8	11.6	4.8
S.E.±	1.83	1.142	0.537
C.D. (P=0.05)	5.37	3.35	1.57
C.V. (%)	30.48	29.37	28.25
Interaction	NS	6.7	3.15
Interaction effects of NPK doses and growth regulators on area lodged (%)			
NPK dose	**Growth regulator**		
	NGR	GRI	GR2
Absolute control	0	0	0
RDF	0	0	0
SSNM-7	38.3	11.7	21.7
SSNM -8	53.3	11.7	25.9
S.E.±	2.28	-----	------
C.D. (P=0.05)	6.7	------	----
Absolute control	0.0	0.0	0.0
RDF	0.0	0.0	0.0
SSNM-7	20.8	4.7	8.3
SSNM -8	29.4	5.0	10.8
S.E.±	1.1	-----	------
C.D. (P=0.05)	3.2	------	----

NS= Non-significant

incidence. Among growth regulators, lodging angle was maximum with NGR which was significantly higher than GR1 and GR2. The difference between GR1 and GR2 was found non-significant. Area per cent lodged was maximum under SSNM-8 which was significantly higher than other NPK doses. No lodging was observed under absolute control and RDF. Among growth regulator, GR1 resulted in minimum area per cent lodged which was significantly lower than other treatments and maximum area per cent lodged was observed under NGR. GR2 resulted in more lodging as compared to GR1. The possible reason may be that GR2 might have resulted in more tiller /m^2 and plant height than GR1 and thus, resulted in more lodging. Lodging score was maximum under SSNM-8 which was significantly higher than other NPK doses and under growth regulator minimum lodging score was under GR1 and maximum under absolute control. Lodging was not observed under absolute control and RDF was applied either with GR1 or GR2 or NGR and area per cent lodged was zero per cent under absolute control and RDF. At higher NPK doses GR1 resulted in lower area per cent lodged both with SSNM-7 and SSNM-8 and was significantly lower than GR2. At SSNM-7 and SSNM-8, maximum area per cent lodged was with NGR and minimum area per cent lodged was along with GR1. GR1 reduced the area per cent lodged by 70 and 78 per cent under SSNM-7 and SSNM-8, respectively as compared to NGR. Similarly GR2, reduce the area per cent lodged by 43 and 52 per cent under SSNM-7 and SSNM-8, respectively as compared to NGR.

Development studies:

The data related to 50 per cent heading, anthesis and physiological maturity are summarized in Table 10. Days taken to 50 per cent heading was affected significantly due to NPK doses and growth regulator. Among NPK doses days taken to 50 per cent heading were maximum under SSNM-8 which was significant from RDF but was at par with absolute control and SSNM-7. Among growth regulators, GR2 had given the highest number of days taken to the 50 per cent heading which was at par with GR1 but was found significant than NGR. The interaction effects between NPK doses and growth regulator on number of days taken to 50 per cent heading were found non-significant. Number of days taken to anthesis was affected significantly due to NPK doses and growth regulators. Among NPK does, SSNM-8 required the highest number of days taken to anthesis which was at par with SSNM-7 but significantly higher than the other treatments. Absolute control and recommended NPK dose was given the equal number of days taken to anthesis which was significantly lower than other treatments. Among growth regulators, GR2 was given the highest number of days taken to anthesis which was significantly higher than other treatments and lowest number days taken to anthesis was under NGR which was at par with GR1. Days taken to physiological maturity were found non-significant due to NPK doses and growth regulators.

Table 10: 50 per cent heading, physiological and harvest maturity influenced by NPK doses and growth regulators

Treatments	Days taken to		
	Heading	Anthesis	Physiological maturity
NPK dose			
Absolute control	98	102	143
RDF	98	102	142
SSNM-7	100	104	143
SSNM -8	100	104	143
S.E.±	0.48	0.46	0.25
C.D. (P=0.05)	1.5	1.4	NS
Growth regulator			
NGR	98	102	143
GR1	100	103	143
GR2	101	105	143
S.E.±	0.41	0.40	0.22
C.D. (P=0.05)	1.2	1.2	NS
C.V. (%)	1.45	1.36	0.53
Interaction	NS	NS	NS

NS= Non-significant

Post harvest studies:

1000 grain weight (g):

In 1000 grain weight, NPK doses and growth regulator registered significant difference. Among NPK doses, 1000 grain weight was recorded significantly higher at recommended NPK. It was higher by 8.6 per cent as compared to absolute control, 7.3 per cent at SSNM-8 and 5.3 per cent at SSNM-7 (Table 11). Among growth regulator doses, 1000 grain weight was recorded higher at GR2 which was significantly higher to NGR but was at par with GRL Interaction effects between NPK doses and growth regulators on 1000 grain weight was significant. The interaction effects between NPK doses and growth regulators on 1000 grain weight were found significant. RDF with GR2 produced maximum 1000 grain weight which was at par with RDF + GR1, RDF+ NGR and SSNM-8+ GR2 but was significantly higher from all the other treatments. Under absolute control, both GR1 and GR2 reduce the 1000 grain weight.

Grain per spike:

The data related to grain per spike are given in Table 11. Grain number per spike differed significantly due to NPK doses. Among NPK doses, RDF was given maximum and significantly higher grains per spike over absolute control but it remained at par with recommended SSNM-7 and SSNM-8. Grains per spike were not affected significantly by growth regulators.

Grain weight (g) per spike:

The data related to grain weight per spike are given in Table 11. Grain weight per spikes was not affected significantly due to NPK doses and growth regulators. Similarly the interaction effects between NPK doses and growth regulators on grain weight per spike were found non-significant.

Fertile spikelets per spike:

The data related to grain/spike are given in Table 11. It was revealed that number of fertile spikelets per spike significantly affected only due to NPK doses. Among NPK doses, SSNM-7 recorded maximum and significantly higher 19.05 number of fertile spikelets per spike absolute control, but remained at par with RDF and SSNM-8. Among growth regulator doses, number

Table 11: Yield attributing characters of wheat influenced by NPK doses and growth regulators

Treatments	1000 grain weight	Grain/ spike	Grain weight/ spike	Fertile spikelet/ spike	Sterile spikelet/spike	Spike length (cm)	Spikes/ m^2
NPK dose							
Absolute control	41.6	32.1	1.9	18.6	3.3	10.4	209
RDF	45.2	43.3	2.1	20.0	3.5	10.9	330
SSNM-7	42.9	41.0	1.9	20.2	3.8	10.9	351
SSNM -8	42.1	41.0	1.8	20.1	3.8	11.4	346
S.E.±	0.353	0.974	0.087	0.36	0.21	0.23	10.07
C.D. (P=0.05)	1.03	2.85	NS	1.07	NS	NS	29.53
Growth regulator							
NGR	42.3	38	2.0	19.6	3.5	11.0	298
GR1	43.0	40	2.0	19.7	3.8	10.9	306
GR2	43.5	40	1.9	19.9	3.5	10.8	322
S.E.±	0.30	0.84	0.07	0.31	0.18	0.20	8.72
C.D. (P=0.05)	0.9	NS	NS	NS	NS	NS	NS
C.V. (%)	2.46	7.42	13.55	5.57	17.52	6.52	9.77
Interaction	1.79	NS	NS	NS	NS	NS	NS

Interaction effects of NPK doses and growth regulators on 1000 grain weight

NPK dose	Growth regulator		
	NGR	GRI	GR2
Absolute control	42.9	41.8	40.2
RDF	44.9	44.8	45.8
SSNM-7	41.2	43.8	43.8
SSNM -8	40.4	41.7	44.3
S.E.±	0.61	-------	--------
C.D. (P=0.05)	1.79	--------	--------

NS= Non-significant

of fertile spikelets per spike was not affected significantly. It ranged from 19.6 to 19.9 fertile spikelets per spike in NGR and GR2, respectively.

Sterile spikelets per spike:

The data related to sterile spikelets per spike are given in Table 11. Sterile spikelets per spike were not affected significantly due to NPK doses and growth regulator. The interaction effects between NPK doses and growth regulator on sterile spikelets per spike were found non-significant.

Spike length (cm):

The data related to spikes length are given in Table 11. Spikes length was not affected significantly both due to growth regulator and NPK doses. Among NPK doses spike length ranged from 10.4 to 11.4 in absolute control and SSNM-8. Among growth regulator spike length ranged from 10.8 to 11 cm with GR2 and NGR, respectively. Similarly interaction between NPK dose and growth regulator was non-significant.

Number of spikes per square meter:

The data related to spikes per square meter are given in Table 11. The number of spikes/m^2 was affected significantly only due to NPK doses. Among NPK doses, SSNM-7 given maximum number of spike/m^2. This was significantly higher than absolute control but remained at par with recommended NPK and SSNM-8. The number of spikes /m^2 was not affected due to growth regulator. Number of spikes/m^2 ranged from 298 to 322 spikes/ m^2 in NGR and GR2, respectively.

Yield studies:

Grain yield:

The data related to grain yield are given in Table 12. Grain yield significantly affected due to NPK doses and growth regulator. Among NPK doses maximum yield *i.e.* 50.5q/ha was obtained under RDF which was 72.3, 12.6 and 17.6 per cent higher than absolute control, SSNM-7 and SSNM-8, respectively. Among growth regulator maximum yield *i.e.* 43.7q/ha was found at GR1 which was 4.85 per cent higher than NGR and 7.1 per cent higher than GR2. Interaction effects between NPK doses and growth regulators were significant. The interaction effects between NPK doses and growth regulator on grain yield was found significant. NPK dose above RDF significantly reduced the grain yield. GR1 produced significantly higher yield than GR2 at particular NPK dose. There was no significant difference between GR2 and NGR at SSNM-7 and SSNM-8. Highest yield *i.e.* 52.6 q/ha was obtained in RDF with GR1 which was significantly higher than other treatments. Yield at SSNM-7 with GR1 was higher than absolute control but it was significantly lower than corresponding RDF. Similarly yield in SSNM-8 with GR1 was significantly higher than GR2 and NGR. RDF with GR1 resulted in increased yield by 6.26 per cent over RDF with NGR. Difference in yield at RDF with NGR and with GR2 was found non-significant. GR1 produced significantly higher yield than with GR2 at any NPK dose. This might be due to fact that cycocel might have shown incompatibility with the fungicide and the crop variety which was used under this trial might be resistant and thus, may have shown no response to the fungicide application. These results suggest that fungicide application to winter wheat can be profitable when environmental conditions favor development of diseases.

Table 12 : Grain yield, biological yield, straw yield and harvest index as affected by treatments

Treatments	Grain yield (q/ha)	Biological yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
NPK dose				
Absolute control	29.7	79.3	49.6	37.6
RDF	50.5	120.7	70.2	41.9
SSNM-7	44.4	115.3	70.9	38.9
SSNM -8	43.0	114.8	71.8	37.8
S.E.±	0.50	1.83	1.85	0.785
C.D. (P=0.05)	1.4	5.3	5.4	2.3
Growth regulator				
NGR	41.2	115.5	74.3	36.0
GR1	43.7	103.6	59.9	42.0
GR2	40.8	103.5	62.7	39.1
S.E.±	0.43	1.58	1.6	0.68
C.D. (P=0.05)	1.2	4.6	4.7	2.0
C.V. (%)	3.58	5.10	8.47	6.03
Interaction	2.52	9.29	9.41	3.99

Biological yield:

The data related to the biological yield are given in Table 12. Biological yield significantly affected due to NPK doses and growth regulator. Among NPK doses highest biological yield of 120q/ha was obtained in RDF which was significantly higher than other NPK doses. Difference between SSNM-7 and SSNM-8 was non-significant. Among growth regulators, biological yield of 115.5q/ha was recorded highest in NGR which was significantly higher to GR1 and GR2 treatments. Difference between GR and GR2 was non-significant. Interaction effect between NPK doses and growth regulators was found significant. Under RDF growth regulators failed to give significant effect on biological yield. However, under SSNM-7 and SSNM-8, growth regulators significantly affect the biological yield. Biological yield was observed maximum under SSNM-7 with absolute control which was at par with RDF+ absolute control, RDF+GR1, RDF+GR2 and SSNM-8 with no growth regulator but was significantly higher than all the other treatments. Biological yield under SSNM-7 and SSNM-8 was reduced possibly due to the reason that higher dose of nutrients resulted in crop lodging and thus reduce the biological yield.

Straw yield:

The data related to straw yield are given in Table 12. Straw yield significantly affected due to NPK doses and growth regulator. Among NPK doses, SSNM-8 given the highest straw yield of 71.8q/ha. It was significantly higher than absolute control but remained at par with RDF and SSNM-7. Among growth regulators, NGR had given highest straw yield of 74.q/ha which was significantly higher than GR1 and GR2. Difference between GR1 and GR2 was found to be non-significant. Interaction effects between growth regulators and NPK dose was found significant. All NPK doses given maximum straw yield with NGR. RDF produced higher straw yield with NGR which was at par with GR1 and GR2. SSNM-7 and SSNM-8 given maximum straw yield with NGR which was significantly higher than GR1 and GR2. Straw yield was decreased in SSNM-7 and SSNM-8 with GR1 and GR2.

Harvest index:

The data related to the harvest index are given in Table 13. Harvest index was affected significantly due to NPK doses and growth regulator. Among NPK doses, harvest index was significantly higher in RDF. Harvest index ranged from 37.6 at absolute control to 41.9 at RDF. Harvest index at SSNM-7 and SSNM-8 was significantly lower than RDF but was at par with absolute control. Among growth regulator harvest index was maximum in GR1 which was significantly higher than GR2 and NGR. Harvest index was significantly affected by interaction of NPK doses and growth regulators. At absolute control and RDF growth regulators failed to give significant effect on HI. However, with SSNM-7 and SSNM-8 GR1 and GR2 resulted in

Table 13 : Interaction effects of NPK doses and growth regulators on grain yield (q/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	31.5	30.5	27.0
RDF	49.5	52.6	49.4
SSNM-7	42.4	46.8	43.9
SSNM -8	41.4	44.8	42.7
S.E.±	0.86	-------	--------
C.D. (P=0.05)	2.52	--------	--------

Table 14 : Interaction effects of NPK doses and growth regulators on biological yield (q/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	84.4	76.4	79.3
RDF	121.6	120.0	120.5
SSNM-7	128.8	109.0	108.1
SSNM -8	127.2	108.9	108.4
S.E.±	3.2	-------	--------
C.D. (P=0.05)	9.29	--------	--------

Table 15: Interaction effects of NPK doses and growth regulators on straw yield (q/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	52.9	45.9	49.9
RDF	72.0	67.4	71.1
SSNM-7	86.5	62.2	64.2
SSNM -8	85.7	64.1	65.6
S.E.±	3.21	-------	--------
C.D. (P=0.05)	9.41	--------	--------

Table 16 : Interaction effects of NPK doses and growth regulators on harvest index (%)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	37.5	40.0	35.3
RDF	40.7	43.9	41.0
SSNM-7	33.0	43.0	40.7
SSNM -8	32.6	41.3	39.5
S.E.±	1.36	-------	--------
C.D. (P=0.05)	3.99	--------	--------

higher HI as compared to NGR. Highest harvest index was found in RDF with GR1.

Plant analysis:

Nitrogen content (%) in grain and straw:

The data related to the nitrogen content in grain and straw are given in Table 17. Among growth regulator nitrogen content in grain was found non-significant. Among NPK doses nitrogen content in grain was found maximum in SSNM-8 which was significantly higher than other treatments and lowest under absolute control which was significantly lower than all treatments. Nitrogen content in grain varied from 1.26 per cent in absolute control to 1.90 in SSNM-8. Among growth regulators maximum nitrogen content in grain was in GR1 which was at par with NGR and GR2. Nitrogen content grain under growth regulator varied from 1.69 per cent in NGR to 1.70 per cent in GR1. Nitrogen content in straw was found significant under NPK doses and growth regulators. Under NPK doses nitrogen content in straw was highest in SSNM-8 which was significant to other treatments. Nitrogen content in straw varied from 0.26 per cent in absolute control to 0.59 per cent in SSNM-8. Under growth regulator it varied from 0.46 per cent in NGR to 0.47 per cent in GR1 and GR2. Interaction between NPK doses and growth regulator on N content in grain and straw was found non-significant.

Table 17: Nitrogen content and uptake by wheat influenced by NPK doses and growth regulators

Treatments	N content and uptake				
	Content (%)		Uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
NPK dose					
Absolute control	1.26	0.26	38.35	12.85	51.24
RDF	1.77	0.46	88.96	33.38	122.36
SSNM-7	1.86	0.54	81.81	45.65	127.28
SSNM -8	1.90	0.59	81.73	47.93	129.28
S.E.±	0.0045	0.0021	1.03	1.47	1.95
C.D. (P=0.05)	0.013	0.0063	3.03	4.31	5.73
Growth regulator					
NGR	1.69	0.46	70.01	35.56	105.10
GR1	1.70	0.47	73.64	33.16	106.81
GR2	1.70	0.47	74.49	36.14	110.65
S.E.±	0.0038	0.0018	0.89	1.27	1.69
C.D. (P=0.05)	NS	0.0054	2.62	NS	NS
C.V. (%)	0.78	1.38	4.27	12.62	5.44
Interaction	NS	NS	5.25	NS	NS

NS= Non-significant

Nitrogen uptake by grain and straw and total uptake:

The data related to the nitrogen up take by grain and straw are given in Table 17. Nitrogen uptake by grain and straw was affected due to NPK doses and growth regulator. Among NPK doses nitrogen uptake by grain was found to be maximum under RDF which was significantly higher than other NPK doses. Among growth regulator nitrogen uptake by grain was found maximum under GR2 which was significantly higher than NGR but was at par with GR1. Under NPK doses highest nitrogen uptake by straw was given to SSNM-8 which was significantly higher than other NPK doses except SSNM-7. Nitrogen uptake by straw was found maximum under GR2 which was at par with other treatments. Under NPK doses total nitrogen uptake was found under SSNM-8 which was significantly higher to all NPK doses except SSNM-7 and lowest was recorded in absolute control. Total nitrogen uptake ranged from 51.24 in absolute control to 129.28 in SSNM-8. Among growth regulators total nitrogen uptake was highest in GR2 which was at par with other growth regulators. Interaction was found to be significant for nitrogen uptake by grain. Nitrogen uptake varied from 35.80kg/ha absolute control with GR2 to 90.40 at RDF with GR2 (Table 18). Under absolute control and RDF, nitrogen uptake was found not to affect with growth regulator. Under SSNM-7 and SSNN-8 nitrogen uptake by grain was highest with GR2 and was at par with GR1 but was significantly higher than NGR.

Table 18: Interaction effects of NPK doses and growth regulators on nitrogen uptake by grain (kg/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	39.30	39.56	35.80
RDF	87.50	89.00	90.40
SSNM-7	777.70	82.83	84.90
SSNM -8	75.16	83.16	86.80
S.E.±	1.79	-------	--------
C.D. (P=0.05)	5.25	--------	--------

Phosphorus content (%) in grain and straw:

The data related to the phosphorus content in grain and straw are given in Table 19. Phosphorus content in

Table 19 : Phosphorus content and uptake by wheat influenced by NPK doses and growth regulators

Treatments	P content and uptake				
	Content (%)		Uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
NPK dose					
Absolute control	0.32	0.09	9.78	4.50	14.29
RDF	0.49	0.18	24.98	12.63	37.31
SSNM-7	0.42	0.13	18.91	11.39	30.30
SSNM -8	0.50	0.19	21.79	13.64	35.42
S.E.±	0.0038	0.0017	0.39	0.462	0.679
C.D . (P=0.05)	0.011	0.0051	1.15	1.35	1.99
Growth regulator					
NGR	0.39	0.14	16.23	11.48	27.71
GR1	0.45	0.15	19.51	10.60	30.41
GR2	0.47	0.15	20.85	11.59	32.45
S.E.±	0.0033	0.0015	0.34	0.4	0.588
C.D . (P=0.05)	0.001	NS	0.99	NS	1.72
C.V. (%)	2.62	3.42	6.26	10.5	6.06
Interaction	NS	NS	1.99	NS	NS

NS= Non-significant

grain and straw was affected significantly due to NPK doses and growth regulator. Among NPK doses nitrogen content of 0.50 per cent in grain was highest in SSNM-8 which was significantly higher than other NPK doses. Whereas absolute control given the lowest phosphorus content of 0.32 per cent in grains. Among growth regulators, maximum phosphorus content in grain was significantly higher in GR2. Phosphorus content in grain ranged from 0.39 per cent to 0.47 per cent in NGR and GR2, respectively. Phosphorus content in straw was significantly affected by NPK doses but was not affected by growth regulators.

Phosphorus uptake by grain and straw:

The data related to phosphorus uptake by grain and straw are given in Table 19. Phosphorus uptake by grain was significantly affected by NPK dose and growth regulator. Among NPK doses, SSNM-8 given the highest phosphorus uptake of 31.76kg/ha by grain. This was significantly higher than other absolute control but was at par with RDF and SSNM-7. Phosphorus uptake by grain ranged from 12.62 kg/ha in absolute control to 31.76kg/ha in SSNM-8.Among growth regulator highest phosphorus uptake by grain was highest in GR2 which was significantly higher than NGR and GR1. Range for phosphorus uptake by grain was from 24.59kg/ha to 28.07kg/ha in NGR and GR2, respectively. Among NPK doses highest phosphorus uptake by straw was in SSNM-8 which was significantly higher than other NPK doses. Phosphorus uptake range by straw was from 4.50kg/ha with absolute control to 15.09kg/ha in SSNM-8. Among growth regulators, phosphorus uptake by straw was found non-significant and it ranged from 10.60kg/ha in GR1 to 11.59k/ha in GR2. Among NPK doses, maximum phosphorus uptake as recorded under RDF which was significantly higher to all other treatments. Total phosphorus uptake ranged from 14.29kg/ha to 38.89kg/ha in absolute control and RDF, respectively. Total phosphorus uptake among growth regulator was found to be maximum under GR2 which was significantly higher than GR1 and NGR. It ranged from 27.71kg/ha in NGR to 11.59kg/ha in GR2. Interaction effects between NPK doses and growth regulator were non-significant for phosphorus uptake by straw but were significant for phosphorus uptake by grain. At any NPK dose it was found that difference between GR1 and GR2 for phosphorus uptake was not significant except for SSNM-8 where phosphorus uptake by GR2 was significantly higher than GR1. Phosphorus uptake under absolute control was not affected by growth regulator.

Table 20: Interaction effects of NPK doses and growth regulators on phosphorus uptake by wheat grain (kg/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	9.13	10.15	10.07
RDF	22.12	25.44	27.37
SSNM-7	15.29	20.01	21.45
SSNM -8	18.40	22.46	24.52
S.E.±	0.68	-------	--------
C.D. (P=0.05)	1.99	--------	--------

Potassium content (%) in grain and straw:

The data related to potassium content in grain and straw are given in Table 21. Potassium content in grain was affected significantly by NPK doses and growth regulator. Among NPK doses highest potassium content was sound in SSNM-8 which was significantly higher than other NPK doses. Potassium content in grain under NPK doses ranged from 0.41 per cent to 0.74 per cent in absolute control and SSNM-8. Potassium content in grain under growth regulator ranged from 0.59 per cent to 0.63 per cent in NGR and GR2, respectively. Among NPK doses maximum potassium content in straw was found in SSNM-8 and lowest was found in absolute control.

Table 21 : Potassium content and uptake by wheat influenced by NPK doses and growth regulators

Treatments	K content and uptake				
	Content (%)		Uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
NPK dose					
Absolute control	0.41	1.10	12.62	53.83	65.46
RDF	0.61	1.30	31.04	93.59	124.63
SSNM-7	0.69	1.42	30.62	118.20	149.47
SSNM -8	0.74	1.51	31.76	122.56	154.32
S.E.±	0.003	0.015	0.40	4.32	4.41
C.D. (P=0.05)	0.010	0.047	1.180	12.670	12.950
Growth regulator					
NGR	0.59	1.32	24.59	101.19	124.49
GR1	0.62	1.34	26.92	91.48	118.40
GR2	0.63	1.32	28.07	98.95	127.02
S.E.±	0.0028	0.0137	0.349	3.74	3.82
C.D. (P=0.05)	0.008	NS	1.02	NS	NS
C.V. (%)	1.6	3.5	4.56	13.3	10.73
Interaction	0.02	NS	2.05	NS	NS

NS= Non-significant

Potassium uptake by grain and straw:

The data related to potassium uptake by grain and straw are given in Table 21. Potassium uptake by grain and straw was significantly affected by NPK doses and growth regulator. Among NPK doses, SSNM-8 gave the highest potassium uptake by grain and was found significantly higher than all other NPK doses except RDF. Among growth regulator potassium content was significantly higher in GR1. Interaction effects for potassium uptake by grain were found significant between growth regulator and NPK doses. Among NPK doses potassium uptake by straw was highest in SSNM-8 which was significant to all NPK doses but was at par with SSNM-7. Potassium uptake by straw under growth regulator was higher in NGR but it was at par with GR1 and GR2. Interaction effects for potassium uptake by straw were found non-significant. Total potassium uptake was significantly affected by NPK doses but was not affected by growth regulator. Among NPK doses total potassium uptake was highest in SSNM-8 which was significantly higher to absolute control and RDF but remained at par with SSNM-7 and lowest in absolute control. At absolute control, growth regulators failed to give significant effect on potassium uptake by grain. At RDF, SSNM-7 and SSNM-8, GR2 significantly resulted in maximum potassium uptake. Highest potassium uptake by grain was recorded in SSNM-8 with GR2 which was significantly higher than all the other treatments. It varied from 11.9kg/ha at absolute control with GR2 to 35.1kg/ha at SSNM-8 with GR2 (Table 22).

Cost of cultivation:

The cost of wheat cultivation increased in fertilizer input and growth regulator. Under NPK doses, SSNM-8 recorded the highest cost of cultivation and under growth regulator GR2 recorded highest cost of cultivation.

Table 22: Interaction effects of NPK doses and growth regulators on potassium uptake by wheat grain (kg/ha)

NPK dose	Growth regulator		
	NGR	GR1	GR2
Absolute control	12.4	13.5	11.9
RDF	29.5	31.3	32.3
SSNM-7	27.8	31.1	30.6
SSNM -8	28.5	31.7	35.1
S.E.±	0.70	-------	--------
C.D. (P=0.05)	2.05	--------	--------

Gross return:

Gross return was affected significantly due to NPK doses and growth regulator. Among NPK doses, the highest gross return was recorded at RDF. It was 63.7 per cent higher than absolute control, 13 per cent higher than SSNM-8 and 10.8 per cent higher than SSNM-7. Among growth regulators, NGR has

Table 23: Effect of NPK doses growth regulators on cost of cultivation, gross return, net return and B: C ratio

Treatments	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C
NPK dose				
Absolute control	19891	55445	355553	1.82
RDF	26155	90797	64642	2.49
SSNM-7	27030	82061	55031	2.05
SSNM -8	28378	80290	51911	1.84
S.E.±	---	783.7	783.8	0.037
C.D. (P=0.05)	-----	2298.4	298.8	0.11
Growth regulator				
NGR	22945	78333	55388	2.41
GR1	25930	78326	52396	2.01
GR2	27216	74786	47570	1.73
S.E.±	----	678.7	678.8	0.032
C.D. (P=0.05)	----	1990.5	1990.8	0.10
C.V. (%)	----	3.04	4.54	5.55
Interaction	----	NS	NS	NS

NS= Non-significant

recorded the highest gross return which was significantly higher than GR2 but remained at par with GR1.Interaction effects between NPK doses and growth regulator were non-significant.

Net return:

Net return under different treatments was affected significantly due to NPK doses and growth regulator. Among NPK doses, the highest net return was recorded at RDF. It was 82, 17 and 25 per cent higher than absolute control, SSNM-7 and SSNM-8, respectively. Among growth regulators, NGR gave highest net return which was significantly higher than GR1 and GR2.

Benefit:cost ratio:

Benefit: cost ratio was affected significantly due to NPK doses and growth regulator. Among NPK doses, the highest benefit: cost ratio was recorded at recommended RDF. It was significantly higher than other NPK doses. The lowest benefit: cost ratio was found in absolute control which was significantly lower than all NPK doses but remained at par with SSNM-8.Among growth regulator the highest benefit: cost ratio was found in NGR which was significantly higher than GR1 and GR2. Lowest benefit: cost ratio was found in GR2.

Experiment 2:

Effect of chemicals on recovery ability of induced lodged wheat:

Morphological indices:

In morphological studies emergence/m^2, tillers/m^2, shoot: emergence ratio, mortality percentage, plant height in cm, dry matter accumulation in gram per square meter and leaf area index were recorded. These parameters were non-significant among the treatments. Emergence ranged from 183 per square meter to 198 per square meter in RDF +IL+ ethrel and in RDF+WL, respectively (Table 24). Tillers start decreasing with the advancement of crop stages and tiller per square meter were found

Table 24 : Emergence and tiller count as affected by treatments

Treatments	Emergence count/m^2	Tiller/m^2			
		30 DAS	60 DAS	90 DAS	120 DAS
RDF+WL	194	456	597	443	383
RDF+IL	194	456	597	443	376
RDF+IL+ Ethrel	183	424	575	432	376
RDF +IL+ KCl	198	428	579	432	374
RDF+IL+ Nano silicon	188	429	582	430	374
C.D. (P=0.05)	NS	NS	NS	NS	NS
S.E.±	12.57	13.30	19.22	9.31	10.10
C.V. (%)	11.38	5.26	5.68	3.70	4.64

NS= Non-significant

Table 25 : Shoot emergence ratio, mortality percentage as affected by treatments

Treatments	Shoot: Emergence ratio					Mortality percentage		
	90DAS	120DAS	90DAS	120DAS	Harvesting	90DAS	120DAS	Harvesting
RDF+WL	2.3	3.1	2.3	2.0	1.5	25.3	35.7	50.0
RDF+IL	2.3	3.1	2.3	1.9	1.5	225.6	36.8	51.8
RDF+IL+ Ethrel	2.3	3.1	2.4	2.1	1.6	24.5	34.5	48.9
RDF +IL+ KCl	2.1	2.9	2.2	1.9	1.5	25.2	35.4	49.7
RDF+IL+ Nano silicon	2.3	2.9	2.3	2.1	1.5	25.9	35.3	51.1
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
S.E.±	0.01	0.19	0.18	0.16	0.1	3.2	2.6	1.9
C.V. (%)	7.5	10.8	13.8	14.2	12.8	22.0	12.5	6.4

NS= Non-significant

Table 26: Plant height as affected by treatments

Treatments	Plant height (cm) days after sowing				
	30DAS	60DAS	90DAS	120DAS	Maturity
RDF+WL	29.7	53.6	85.6	102.9	101.2
RDF+IL	29.7	53.6	85.2	101.9	100.5
RDF+IL+ Ethrel	29.1	51.2	85.1	101.0	95.9
RDF +IL+ KCl	29.2	53.4	85.7	102.2	97.1
RDF+IL+ Nano silicon	28.9	52.3	85.6	102.3	96.8
C.D. (P=0.05)	NS	NS	NS	NS	NS
S.E.±	0.78	1.56	0.82	0.70	1.17
C.V. (%)	4.63	5.12	1.65	1.20	2.06

NS= Non-significant

maximum at 60 DAS. Tillers were found non-significant at all growth stages. Thus, it may be concluded that artificially induced lodging at grain filling stage did not affect the tillers per meter square. Shoot: emergence ratio was found non-significant at all growth stages. Shoot: emergence ratio was recorded maximum at 60 DAS. Mortality percentage was also found non- significant at 90 and 120DAS and at harvesting. At harvesting mortality percentage ranged from 49.0 per cent in RDF+ ethrel to 51.8 per cent in RDF+IL (Table 25). Plants height was found non-significant among various treatments at all growth stages. Plant height at maturity was found to be maximum under RDF +WL, but remained at par with all other treatments. RDF+ ethrel reduced the plant height at maturity but the reduction in plant height was not significant with other treatments. Plant height at maturity ranged from 95.9 cm to 101.2 cm in RDF+IL+ ethrel and RDF+WL, respectively (Table 26). Reduced plant height under RDF+ ethrel may be due to fact that ethrel releases ethephon which is growth retardant and reduces the plant height. Dry matter accumulation was non-significant at all growth stages except at 120DAS. At 120 DAS dry matter was significantly higher in RDF+WL. At 120DAS, dry matter per square meter ranged from 1624 to 1185 in RDF+WL and RDF+IL, respectively (Table 27). In induced lodging treatments dry matter was not affected by the application of chemicals. LAI was non-significant at all growth stages (Table 28). LAI increased with the advancement of crop stage and maximum leaf area index was recorded at 120DAS. At 120DAS leaf area ranged from 3.82 to 3.94 in RDF+IL+ KC1 and RDF+WL, respectively. Peduncle length was found significant among various treatments (Table 29). It was maximum in RDF+WL which was significantly higher than all treatments except than RDF +IL+ ethrel and RDF+IL+ nano-silicon. Peduncle length ranged from 28.6cm to 32.3cm in RDF+ ethrel and RDF+WL, respectively. 1st internode length was found non-significant among treatments at 90 and 120DAS. 2nd internode length at 90 DAS was non-significant among treatments. At 120 DAS, 2nd internode length was higher in RDF+ WL which was significantly higher than other treatments except to RDF+IL. Application of ethrel, KC1 and nano-silicon thus, reduced the 2nd internode length significantly in wheat after induced lodging.

Table 27: Dry matter accumulation (g/m^2) as affected by treatments

Treatments	Dry matter (g/m^2) days after sowing			
	30DAS	60DAS	90DAS	120DAS
RDF+WL	87.4	492.0	817.9	1624.0
RDF+IL	87.4	492.0	817.9	1185.0
RDF+IL+ Ethrel	79.8	466.0	826.6	1235.0
RDF +IL+ KCl	80.8	492.0	835.0	1262.0
RDF+IL+ Nano silicon	80.2	482.9	806.2	1261
C.D. (P=0.05)	NS	NS	NS	172.80
S.E.±	4.44	11.17	13.40	53.04
C.V. (%)	9.25	3.99	2.82	6.97

NS= Non-significant

Table 28: Leaf area index as affected by treatments

Treatments	Leaf area index			
	30DAS	60DAS	90DAS	120DAS
RDF+WL	1.35	3.2	3.8	3.94
RDF+IL	1.35	3.19	3.78	3.87
RDF+IL+ Ethrel	1.23	2.94	3.68	3.79
RDF +IL+ KCl	1.25	3.09	3.7	3.82
RDF+IL+ Nano silicon	1.24	3.03	3.68	3.83
C.D. (P=0.05)	NS	NS	NS	NS
S.E.±	0.0685	0.068	0.089	0.1
C.V. (%)	9.21	3.86	4.16	4.9

NS= Non-significant

Table 29: Peduncle length (cm) and internode length (cm) as affected by treatments

Treatments	Peduncle length (cm)	1st internode length (cm)		2nd internode length (cm)	
		90 DAS	120 DAS	90 DAS	120 DAS
RDF+WL	32.3	30.7	34.9	14.3	17.3
RDF+IL	32.1	30.6	34.9	14.3	17.3
RDF+IL+ Ethrel	28.6	29.2	32.8	13.8	14.7
RDF +IL+ KCl	31.0	28.9	33.4	14.1	15.2
RDF+IL+ Nano silicon	28.9	29.8	33.3	14.0	15.1
C.D. (P=0.05)	2.55	NS	NS	NS	0.96
S.E.±	0.78	0.65	0.52	0.06	0.30
C.V. (%)	4.43	3.76	2.65	1.75	3.20

NS= Non-significant

Phenological studies:

Days taken to 50 per cent heading, anthesis and physiological maturity were recorded and the data are given in Table 30. Days taken to 50 per cent heading and anthesis was not affected by treatments. Days taken to physiological maturity were significant among treatments. Maximum days taken to physiological maturity were given to RDF+IL+ ethrel which was significantly higher than RDF+WL and RDF+IL, but was at par with RDF+ IL+ KC1 and RDF+IL+ nano-silicon. The possible reason of such results in phonological indices might be due to fact

Table 30: Days taken to heading, anthesis and physiological maturity as affected by treatments

Treatments	Heading	Anthesis	Physiological maturity
RDF+WL	97.6	102.0	142.7
RDF+IL	97.6	102.7	142.6
RDF+IL+ Ethrel	99.0	102.6	143.7
RDF +IL+ KCl	98.3	102.3	144.7
RDF+IL+ Nano silicon	97.6	102.0	143.6
C.D. (P=0.05)	NS	NS	1.33
S.E.±	1.08	1.25	0.40
C.V. (%)	1.91	2.12	0.50

NS= Non-significant

Table 31: Lodging angle, area lodged (%) and lodging score as affected by treatments at harvesting

Treatments	Lodging angle	Area lodged (%)	Lodging score
RDF+WL	0	0	0
RDF+IL	86.6	88.33	85.1
RDF+IL+ Ethrel	73.3	83.3	67.8
RDF +IL+ KCl	71.7	83.3	66.3
RDF+IL+ Nano silicon	71.6	81.6	64.9
C.D. (P=0.05)	5.29	5.29	6.65
S.E.±	1.62	1.62	2.04
C.V. (%)	4.63	4.17	6.22

that lodging was induced at later growth stages hence, not affecting 50 per cent heading and anthesis. Physiological maturity was delayed by the application of chemicals like ethrel, KC1 and nano-silicon.

Lodging observations:

Lodging angle, area per cent lodged and lodging score were recorded and data are given in Table 31. At time of lodging wheat was almost flat with the ground in artificially induced treatments. Lodging observations like lodging angle, area per cent lodged and lodging score were recorded at time of harvesting. Lodging angle was significantly affected by treatments. No lodging was observed in RDF +WL at the time of harvesting. Among induced lodging treatments at the time of harvesting maximum lodging angle, area per cent lodged and lodging score was recorded in RDF +IL treatment which was significantly higher to all treatments and minimum angle was in RDF+ IL+ nano-silicon. At the time of harvesting it as observed that lodging angle was reduced from initially 90° to various angles with maximum reduction in RDF+ IL+ nano silicon where angle of lodging was reduced to 71.6° and was at par with RDF+IL+ ethrel and RDF+ IL+KC1 treatments but was significantly lower than angle in RDF+IL in which angle was reduced to 86.6°. This indicate that wheat crop has little or no ability to recover from lodging if lodging occurs at or after grain filling stage, however, foliar application of ethrel, nano-silicon and potassium chloride have partially make the crop to re-erect somewhat and it was observed at harvesting time that upper one third portion of stem was in upright position. This appears to be associated with the upper one or two internode bending upwards to partially re-erect the crop. Area per cent lodged was significantly affected by treatments. It was maximum in RDF+IL which was significantly higher than other treatments and minimum was in RDF+IL+nano-silicon. Per cent area lodged which was about 95-100 per cent at the time of lodging seems to be lowered down as the crop partially re-erected with the time and it was observed that about 81.6 per cent area was lodged at the time of harvesting where nano-silicon was applied and this was the lowest area per cent lodged and highest per cent area was under RDF+IL. Lodging score was significantly affected by treatments. Lodging score was maximum under RDF+ IL which was significantly higher than all treatments and lowest was in RDF+IL+ nano-silicon. Thus, it may be concluded that application of different chemicals have shown positive effect of lodged crop and make the crop re-erect to some extent.

Table 32 : Yield attributing characters as affected by treatments

Treatments	1000 grain weight	Grain/ spike	Spikes /m^2	Spikelet/ spike	Sterile spikelet/ spike	Grain weight/ spike	Spike length (cm)
RDF+WL	44.8	42.2	329.0	20.6	2.9	2.1	11.3
RDF+IL	38.8	34.5	321.0	20.6	4.0	2.0	11.3
RDF+IL+ Ethrel	43.8	38.0	326.0	20.4	3.9	2.0	11.2
RDF +IL+ KCl	41.1	37.0	327.0	20.4	4.0	2.0	11.2
RDF+IL+ Nano silicon	44.2	37.8	327.0	20.5	3.7	2.1	11.1
C.D. (P=0.05)	4.60	5.68	NS	NS	0.7	NS	NS
S.E.±	1.71	1.74	9.42	0.27	0.213	0.88	0.52
C.V. (%)	5.80	8.15	4.78	2.28	9.94	15.35	8.0

NS= Non-significant

Post harvest studies:

Yield attributing characters:

In yield attributing characters spike/m^2, peduncle length, spike fertile spikelets/ spike, grains/ spike and 1000 grains weight were measured. Among these characters 1000 grain weight and grains per spike were significantly affected by treatments. 1000 grain weight was found to be under RDF+WL which was significantly higher than RDF+IL but was at par with other treatments. In this study there was reduction in 1000 grain weight by 14 per cent in RDF+IL as compared to RDF+WL. Grains per spike were highest in RDF+WL which was significantly higher than RDF+IL but remained at par with other treatments. Sterile spikelet was maximum under RDF+WL and was significantly higher than all the other treatments. Other characters were not affected by treatments. Spikes/m^2 was maximum in RDF+WL which were at par with all treatments. Spike per square meter ranged from 321 to 329 in RDF+IL and RDF+WL, respectively. Spikelets per spike was higher in RDF+WL this was at par with all treatments (Table 32).

Grain yield, biological yield, straw yield and harvest index:

Data related to grain yield biological yield straw yield and harvest index is given in Table 33. All these parameters except straw yield were significantly affected by treatments. Grain yield was recorded maximum in RDF+WL treatment which was significantly higher than all other treatments. Lodging reduced grain yield and it was observed that yield reduction was 45 per cent in RDF+IL as compared to RDF+WL. Application of ethrel, and nano-silicon produced higher grain yield as compared to RDF+IL treatment. However, KC1 application produced the yield which was at par with RDF+IL. Biological yield was significantly affected by treatments and maximum biological yield was recorded in RDF+WL which was significantly higher than other treatments. It ranged from 85q/ha to 121.5q/ha in RDF+IL and RDF+WL, respectively. Straw yield was non- significant among treatments. HI was highest in RDF+WL which were significantly higher as compared to other treatments. Harvest index ranged from 32.2 per cent to 40.7 per cent in RDF+IL and RDF+WL treatments, respectively. In this study it was observed that yield was reduced by 45 per cent due to lodging in RDF+ IL treatment as compared to RDF+WL.

Table 33 : Grain yield (q/ha), biological yield (q/ha), straw yield (q/ha) and HI (%) as affected by treatments

Treatments	Yield	Biological yield	Straw yield	HI
RDF+WL	49.5	121.5	72.0	40.7
RDF+IL	27.2	85.0	57.8	32.2
RDF+IL+ Ethrel	30.9	93.5	62.6	33.0
RDF +IL+ KCl	30.1	93.0	63.0	32.3
RDF+IL+ Nano silicon	31.5	95.6	64.1	33.0
C.D. (P=0.05)	3.45	8.16	NS	4.57
S.E.±	1.05	2.50	2.70	1.40
C.V. (%)	5.42	4.43	7.33	7.10

NS= Non-significant

Nutrient studies:

NPK content and uptake by grain, straw and total uptake were analysed. Nitrogen content in grain was significantly affected by treatments. Nitrogen content in grain was observed maximum under RDF+ IL+ KC1 and RDF +IL+ ethrel which was significantly higher than other treatments except with RDF+IL+ nano-silicon. Nitrogen content in straw was not affected by treatments. Nitrogen uptake in grain was observed maximum under RDF+ WL, which was significantly higher than other treatments. Nitrogen uptake was significantly affected by treatments and maximum nitrogen uptake by grain was recorded in RDF+WL which was significantly higher to all other treatments. Nitrogen uptake by grain ranged from 47.8kg/ha to 87.8kg/ha in RDF+IL and RDF+ WL, respectively. Nitrogen uptake in straw was not affected by treatments. Total nitrogen uptake was significantly affected by different treatments and was observed maximum under RDF+WL and was significantly higher than all treatments. Total nitrogen uptake ranged from 74.2kg/ha to 120kg/ha in RDF+IL and RDF + WL, respectively (Table 34).

Table 34 : Nitrogen content (%) and uptake (kg/ha) as effected by treatments

Treatments	N content (%)		N uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
RDF+WL	1.77	0.45	87.80	32.80	120.70
RDF+IL	1.75	0.45	47.80	26.30	74.20
RDF+IL+ Ethrel	1.78	0.45	56.50	28.10	84.60
RDF +IL+ KCl	1.78	0.46	54.20	29.40	83.70
RDF+IL+ Nano silicon	1.77	0.45	57.90	29.20	87.20
C.D. (P=0.05)	0.01	NS	3.3	NS	4.46
S.E.±	0.0047	0.0035	1.02	1.28	1.37
C.V. (%)	0.46	1.32	2.9	7.59	2.63

NS= Non-significant

Phosphorus content and uptake by grain, straw and total uptake are given in Table 35. Phosphorus content in grain and straw was not affected by treatments. Phosphorus uptake by grain and straw was significantly affected by treatments. Phosphorus uptake by grain was observed maximum under RDF+WL which was significantly higher than other treatments and lowest phosphorus uptake was under RDF+IL. Phosphorus uptake by straw was found maximum under RDF + WL which was significantly higher than all other treatments. Total phosphorus uptake was observed maximum under RDF+WL, which was significantly higher to all other treatments. Total phosphorus uptake ranged from 22.8kg/ha to 36.7kg/ha RDF+IL and RDF+WL, respectively.

Potassium content and uptake in grain, straw and total uptake are given in Table 36. Potassium content in grain and straw was significantly affected by treatments. Potassium content in grain and straw was observed maximum under RDF+ IL+KC1, which was significantly higher than other treatments. Potassium uptake by grain was significantly affected by treatments and highest potassium uptake by grain was observed with RDF+WL, which was significantly higher to all other treatments. Total potassium uptake significantly affected by treatments and it was observed highest under RDF+WL which was significantly higher than other treatments. Total potassium uptake range was from 95.57kg/ha in RDF+IL to 123.4kg/ha in RDF+WL.

Table 35 : Phosphorus content (%) and uptake (kg/ha) as effected by treatments

Treatments	P content (%)		P uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
RDF+WL	0.46	0.19	22.70	13.96	36.70
RDF+IL	0.45	0.18	12.40	10.40	22.80
RDF+IL+ Ethrel	0.45	0.18	14.40	11.25	25.75
RDF +IL+ KCl	0.45	0.19	13.70	12.10	25.94
RDF+IL+ Nano silicon	0.45	0.18	14.90	11.54	26.44
C.D. (P=0.05)	NS	NS	0.99	1.5	1.41
S.E.±	0.0032	0.0026	0.3	0.46	0.433
C.V. (%)	1.23	2.4	3.36	6.47	2.67

NS= Non-significant

Table 36 : Potassium content (%) and uptake (kg/ha) as effected by treatments

Treatments	K content (%)		K uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total
RDF+WL	0.59	1.30	29.55	93.80	123.40
RDF+IL	0.59	1.30	16.25	75.32	95.57
RDF+IL+ Ethrel	0.59	1.29	18.84	84.40	99.04
RDF +IL+ KCl	0.63	1.34	19.25	84.85	104.40
RDF+IL+ Nano silicon	0.58	1.29	19.23	82.72	101.80
C.D. (P=0.05)	0.0157	0.009	1.16	NS	11.50
S.E.±	0.48	0.00287	0.36	3.55	3.52
C.V. (%)	1.39	0.38	3.0	7.36	5.85

NS= Non-significant

Table 37 : Cost of cultivation, gross return, net return and B: C ratio as affected by treatments

Treatments	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
RDF+WL	23650	89783.0	66133.0	2.8
RDF+IL	25650	53932.0	28282.0	1.1
RDF+IL+ Ethrel	26670	60478.0	33008.0	1.3
RDF +IL+ KCl	26450	5933.0	3288.0	1.2
RDF+IL+ Nano silicon	42685	61647.0	18963.0	0.4
C.D. (P=0.05)	----	4626.1	4626.1	0.17
S.E.±	-----	1419.3	1419.3	0.054
C.V. (%)	-----	3.78	6.82	6.9

Nitrogen content in grain was higher in ethrel and KC1 treatments. This may be due to fact that ethrel has resulted in higher nitrogen use efficiency. Potassium chloride also may result in higher nitrogen content in grain. However, phosphorus content was not affected by application of different chemicals like ethrel, KC1 and nano-silicon. Potassium content in grain and straw was observed higher in KC1 application this may be due to fact that additional foliar spray at grain filling stage resulted in higher potassium content in grain and straw.

Economic analysis:

Gross return, net return and benefit: cost was significantly affected by treatments. Highest gross return/ ha was obtained in RDF+WL which was significantly higher than all other treatments and lowest gross return was obtained under RDF+IL. Net return /ha was highest in RDF+WL and lowest in RDF+ IL+nano-silicon. Benefit: cost ratio was highest under RDF+WL and lowest under RDF + IL+ nano-silicon. Gross returns were increased by 14, 12 and 10 per cent by nano-silicon, ethrel and KC1 application as compared to RDF+IL treatment. Net returns by ethrel and KC1 were increased by 19.5 and 16.3 per cent, respectively as compared to RDF+ IL. However, net returns by nano-silicon were decreased by 32 per cent as compared to RDF+IL. This is due to fact that cost of cultivation in RDF+IL+ nano-silicon was higher than RDF+IL and thus, resulted in minimum net return and B:C (Table 37).

Conclusion :

It is concluded from the experiment that lodging significantly reduced the grain yield. Recommended dose of fertilizer 150:60:40kg /ha was efficient for maximum growth and yield, higher gross return, net return and minimum crop lodging. Subsequent increase in nutrient doses resulted in crop lodging which ultimately reduced the grain yield. Cycocel can be used to reduce the crop. Cycocel alone proved to be more effective in lodging management and increase in yield as compared to when cycocel was mixed with fungicide. Under artificially crop lodging situations ethrel or potassium chloride may prove to be beneficial since these chemicals can reduce the yield loss by lodging as these can make the crop to recover from lodging. However, these results are based on one season data further investigations are required to study the causes and effects so as to validate the possible benefits to farming community.

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