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RESEARCH ARTICLE

Balancing grain and fodder: A study of wheat varieties under variable inputs in semi-arid zone of Haryana, India

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Abstract

The study was carried out at research farm of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India during *Rabi* seasons of 2017-18 and 2018-19. The field experiment was conducted in Split Plot Design with 2 wheat varieties i.e. C 306 and WH 1105 taken with cut and no-cut management in main plot and two seed rates (100 kg/ha and 125 kg/ha) with 3 fertilizer levels (100 %, 115 % and 130 % recommended dose of fertilizer) in sub plot with 3 replications. Results showed that significantly more protein and crude protein yield (741.15 and 691.35 kg/ha), nitrogen, phosphorus and potassium (NPK) content, uptake in grain and straw, more grain yield among both varieties were recorded in no-cut plots as compared to cut-plots whereas, more available NPK in soil of WH 1105 wheat variety was observed in cut-plots as compared to no-cut plots with either seed rate throughout the experiment. Considerably higher available NPK in soil was observed in wheat sown with 130 % RDF over wheat sown with 100 % RDF with either seed rate during both the years. Higher seed rate resulted in lower NPK in soil with lower fertilizer levels. The correlation of grain yield was negative with leaf area index and test weight while with all other recorded parameters it was positively correlated. The principal components (PC_1 and PC_2) were worked out and asserted a very high cumulative variance of 88.44 %. Cutting wheat for fodder severely reduced growth and yield in WH 1105, even with increased seed and fertilizer levels, making it uneconomical for dual purpose. Cultivar C 306 showed reduced growth after cutting but maintained grain yield when given 115 % and 130 % RDF with recommended seed rate. C 306 is a good choice for dual-purpose, offering fodder with minimal yield penalty under higher fertilizer dose.

Keywords: nutrient content; quality; wheat varieties; correlation; PCA; yield

Introduction

Livestock is very important sector of agriculture and constitutes a big portion of agricultural GDP of India. It has played an important role in generating revenue through milk processing, meat, butter, wool, compost manure and agricultural operations in households (1). As we know that arable land for forage production is decreasing day by day, so a remarkable pressure has been created by livestock sector to meet their feed requirements (2). The projected fodder scarcity in India reveals a net deficit of 35.6 % green fodder and 10.9 % dry crop residue which calls for development and adoption of some novel agronomic interventions to manage this forage deficit. The growing of dual-purpose cereal crops i.e. fodder at vegetative phase and grain at maturity, will meet the requirement of both livestock and human population (3-5). Cutting management in wheat has great potential to make available the high-quality forage to livestock population of country in order to fill up the gap in forage supply. It also increases the profitability of farmers by overcoming the grain yield losses through the income generated from forage production. In this context, increases in agricultural land productivity that satisfy the food demand and the animals' nutritional needs of interest to policymakers.

To address the challenge of a continuously increasing population and decreasing wheat cultivation area, a key solution lies in enhancing food grain yield. Grain yield in cereals is the function of the several attributes like spike number per unit area, number of kernels per spike and test weight. It could be improved through efficient agronomic practices like cultivation of high yielding varieties, optimum application of nutrients and irrigation and pest management. Macronutrient plays decisive role in crop nourishment and thus helps in achieving satisfactory progression of plants leading to higher yield (6).

Removing aerial parts of plant could lead to reduction of grain yield in winter cereals due to leaf area and tiller senescence constraints which cause less assimilation of photosynthates during flowering stage in reproduction phase (7). Number of cuts in plant may also affect the yield attributing

characters, thereby, affecting grain yield. Different yield attributing characters are diligently related to various yield and quality traits and due to cut management and fertilization practices, they can impede development by reducing the desired qualitative characteristics of the product.

Crop productivity is fundamentally influenced by effective agronomic management practices, among which seed rate and nutrient management are paramount. Optimizing the seed rate is crucial as it determines the plant population per unit area, directly impacting the ability of the crop to capture vital resources like light, water and nutrients. An inappropriate or suboptimal seed rate can lead to excessive inter-plant competition or poor stand establishment, ultimately resulting in reduced tillering, lower yield components and diminished grain yield and enhanced RDF can boost production, studies on nutrient management also highlight the need for balanced fertilization to prevent soil fertility deterioration and maximize nutrient use efficiency (8). Enhanced levels are often studied to see if the crop benefits from a slightly higher input, especially under specific conditions like high plant density or specific soil deficiencies (9). In this context, our research contributes to the analysis of the productivity of agricultural soil in two directions. This study revisits a key debate in agricultural economics - how to ensure food security and sustainable animal nutrition amid shrinking arable land. A major challenge lies in identifying effective strategies to sustain or enhance productivity despite land constraints caused by agricultural expansion. To address this, we employ principal component analysis (PCA) to assess dual-purpose wheat in terms of biomass yield, nutrient content, nutrient uptake, grain and forage quality and soil health indicator.

It was hypothesized that producing green fodder of crop additional to the grain yield will help in managing the winter feed (green fodder) gap to the livestock/animals. In a connection of this, a field study was carried out to evaluate the effect of different levels of seed rate and fertilizer on fodder production of tall and dwarf wheat during *Rabi* seasons to overcome the shortage of green fodder supply during lean periods.

Materials and Methods

The study was carried out at research farm of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar Haryana, in 2017-18 and 2018-19 (Fig. 1). The experimental site is situated at 29°10" N latitude and 75°46" E longitude with 215.2 m above mean sea level in north-west part of India. The mean weekly maximum temperature ranged between 18.2 °C to 40.0 °C and minimum between 3.2 °C to 20.6 °C and relative humidity morning ranged between 53.9 % to 98.1 %, while relative humidity evening ranged between 22.5 % to 69.0 % respectively. Field soil belongs to inceptisol order and sandy loam texture with 55 % sand, 34 % silt, 11 % clay and slightly alkaline, exhibiting a pH value of 7.9. Field soil contains organic carbon (0.44 %), available nitrogen (128 kg/ha), medium phosphorus (28.5 kg/ha) and available potassium (378 kg/ha), the fertility status of the experimental area was poor. The month wise total precipitation, average maximum temperature; minimum temperature, relative humidity (morning and evening), sunshine hr and evaporation of experimental site of both crop seasons are depicted in Table 1.

Experimental details

The field study was carried in Split Plot Design with 3 replications, comprising 4 treatments in main-plots viz: C 306 with no-cut (M_1), C 306 with cut at 60 days after sowing (DAS) (M_2), WH 1105 with no-cut (M_3), WH 1105 with cut at 60 DAS (M_4) and six combinations of seed rate and fertilizer levels viz. 100 kg ha^{-1} seed rate + 100 % RDF (S_1), 100 kg ha^{-1} seed rate + 115 % RDF (S_2), 100 kg ha^{-1} seed rate + 130 % RDF (S_3), 125 kg ha^{-1} seed rate + 100 % RDF (S_4), 125 kg ha^{-1} seed rate + 115 % RDF (S_5) and 125 kg ha^{-1} seed rate + 130 % RDF (S_6) in subplots. The gross plot size was 10.0 m × 2.0 m and net plot size was 10.0 m × 1.8 m with 20

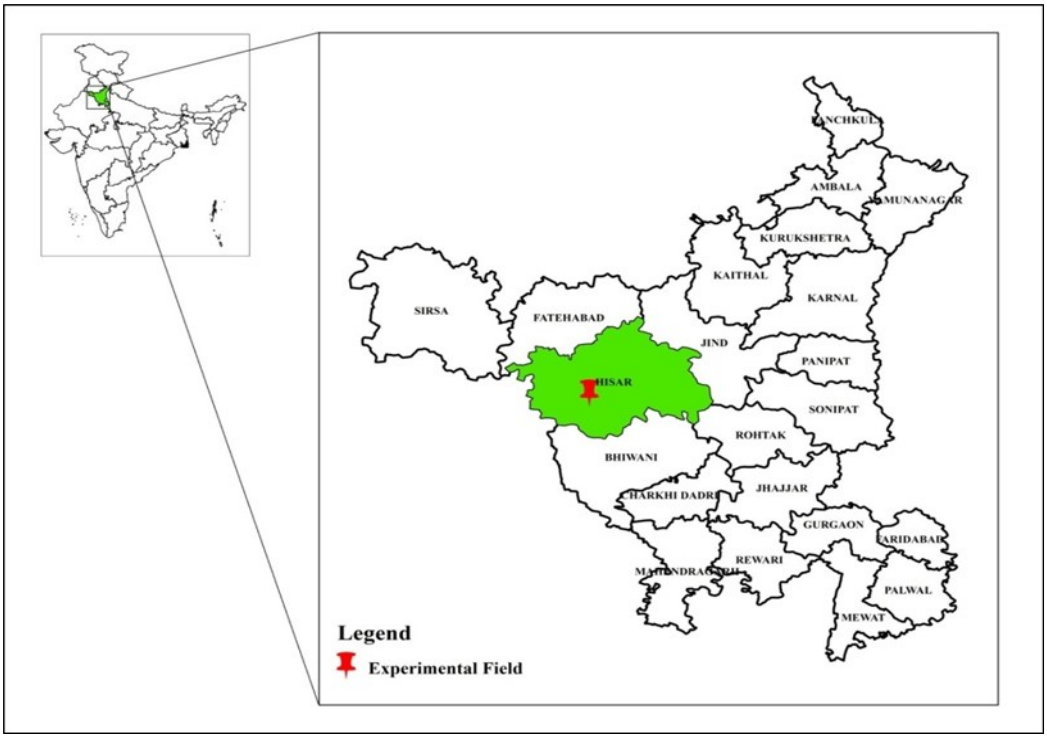

Fig. 1. Geographical location of the study area.

Table 1. Monthly actual weather parameters of the experimental site during 2017-18 and 2018-19

Season	T_{max}* (°C)	T_{min}* (°C)	RHm* (%)	RHe* (%)	Sunshine (hours)	Rainfall (mm)	Evaporation (mm)
			***Rabi* 2017-18**				
November	27.2	10.8	90	40	3.4	0.0	2.8
December	22.3	6.1	91	43	5.2	3.8	1.3
January	20.3	4.8	96	56	5.4	10.9	1.2
February	24.5	7.9	91	55	6.7	1.2	2.0
March	30.9	12.2	82	36	6.9	0.0	3.6
April	36.7	19.5	60	33	7.3	14.0	6.4
			***Rabi* 2018-19**				
November	27.9	11.7	90	46	4.2	0.0	2.1
December	21.9	4.9	93	50	4.9	0.0	1.2
January	19.2	5.2	94	60	4.6	13.8	1.1
February	20.4	8.0	92	59	4.6	8.8	1.6
March	26.5	10.4	87	43	6.6	6.0	3.0
April	36.7	18.4	69	27	7.8	8.2	6.5

*T_{max}- Maximum temperature, T_{min}-Minimum temperature, RHm & RHe -Relative humidity-morning & evening, respectively.

cm row to row spacing and 5 cm plant to plant spacing. In the first-year trial sowing of the crop was done on 7th November 2017 and sowing of 2nd trial was done on 13th November 2018. Recommended doses of NPK as per the treatments were applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP) respectively. N fertilizer was applied in 2 splits in without cut i.e. half at sowing time and rest half at first irrigation, whereas, in cut management N was applied in 3 splits i.e. 50 % as basal dose, 25 % after first irrigation and 25 % after cut. The Absolute growth rate (AGR) was calculated (10). Nitrogen content in nitrogen content in grain and straw of samples was determined by a colorimetric method (11), phosphorus content by Vanadomolybdo-phosphoric acid yellow color method (12) and potassium content by flame photometer method (13). The protein and crude protein content in grain were calculated by multiplying the factor 6.25 and 5.83 respectively, with % N content of the grain. The experimental data for various parameters was statistically analysed by the methods of analysis of variance (ANOVA) and except PCA was analysed by R software (14).

Results and Discussion

Absolute Growth Rate (AGR)

In case of main plots or factor, significantly higher absolute growth rate of 2.01 and 8.62 g/day was observed in C 306 variety without cut over WH 1105 for the period between 0-30 and 31-60 DAS (before harvest) respectively whereas during 61-90 DAS, 91-120 DAS and 121 DAS at harvest, significantly higher absolute growth rate of 11.63, 27.46 and 13.48 g/day respectively was observed in WH 1105 over C 306 (Fig. 2).

In case of seed rate and fertilizer combination treatments, significantly higher absolute growth rate of 1.93, 8.49, 8.40, 19.81 and 9.95 g/day was observed in wheat sown at 125 kg/ha seed rate with 130 % RDF for the period between 0-30, 31-60, 61-90, 91-120 DAS and 121 DAS-at harvest respectively which was statistically at par with wheat sown at 125 kg/ha seed rate with 115 % RDF and wheat sown at 100 kg/ha seed rate with 130 % RDF during both the years. Significantly lowest absolute growth rate of 1.87, 8.14, 7.53, 18.49 and 8.06 g/day was observed in wheat sown at 100 kg/ha seed rate with 100 % RDF for the period between 0-30, 31-60, 61-90, 91-120 DAS and 121 DAS at harvest respectively.

Nutrient content and uptake in grain and straw

The perusal of data presented in Fig. 3 (a-d) shows the effect of different seed and fertilizer levels on NPK content and uptake in grain and straw of dual purpose tall and dwarf wheat during 2017-18 and 2018-19. For both the wheat varieties significantly higher nutrient content and uptake in both grain and straw were observed in no-cut plots as compared with cut-plots with either seed rate during both years of study. It might be due to the absence of cutting shock with no interruption in normal plant growth under no-cut situation. Among both of the varieties,

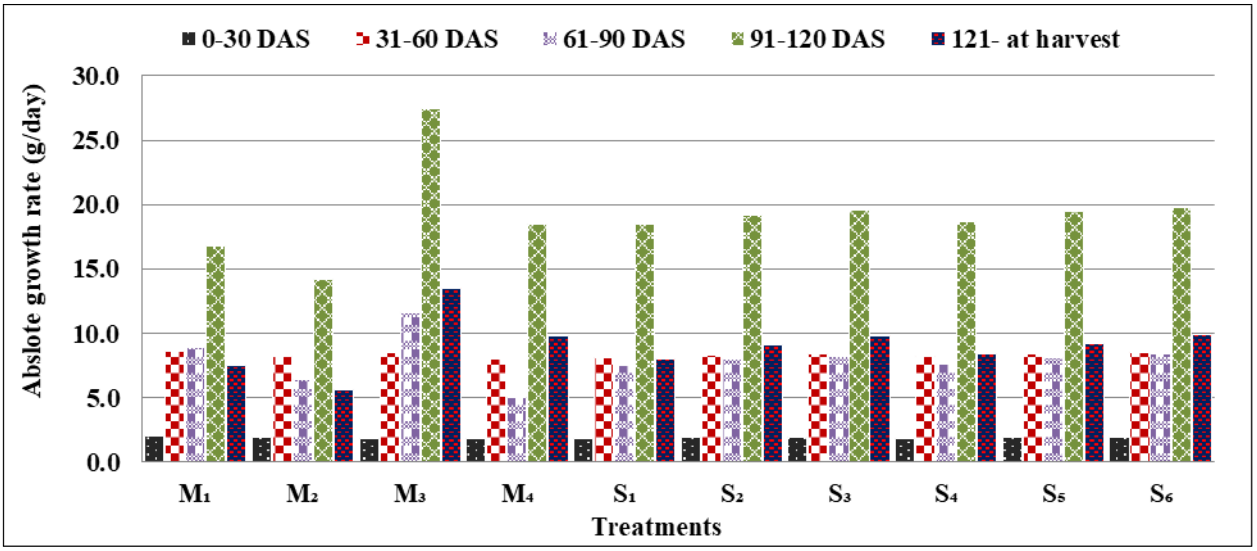

Fig. 2. Impacts of various rates of seed and levels of fertilizer on absolute growth rate of dual purpose tall and dwarf wheat varieties.

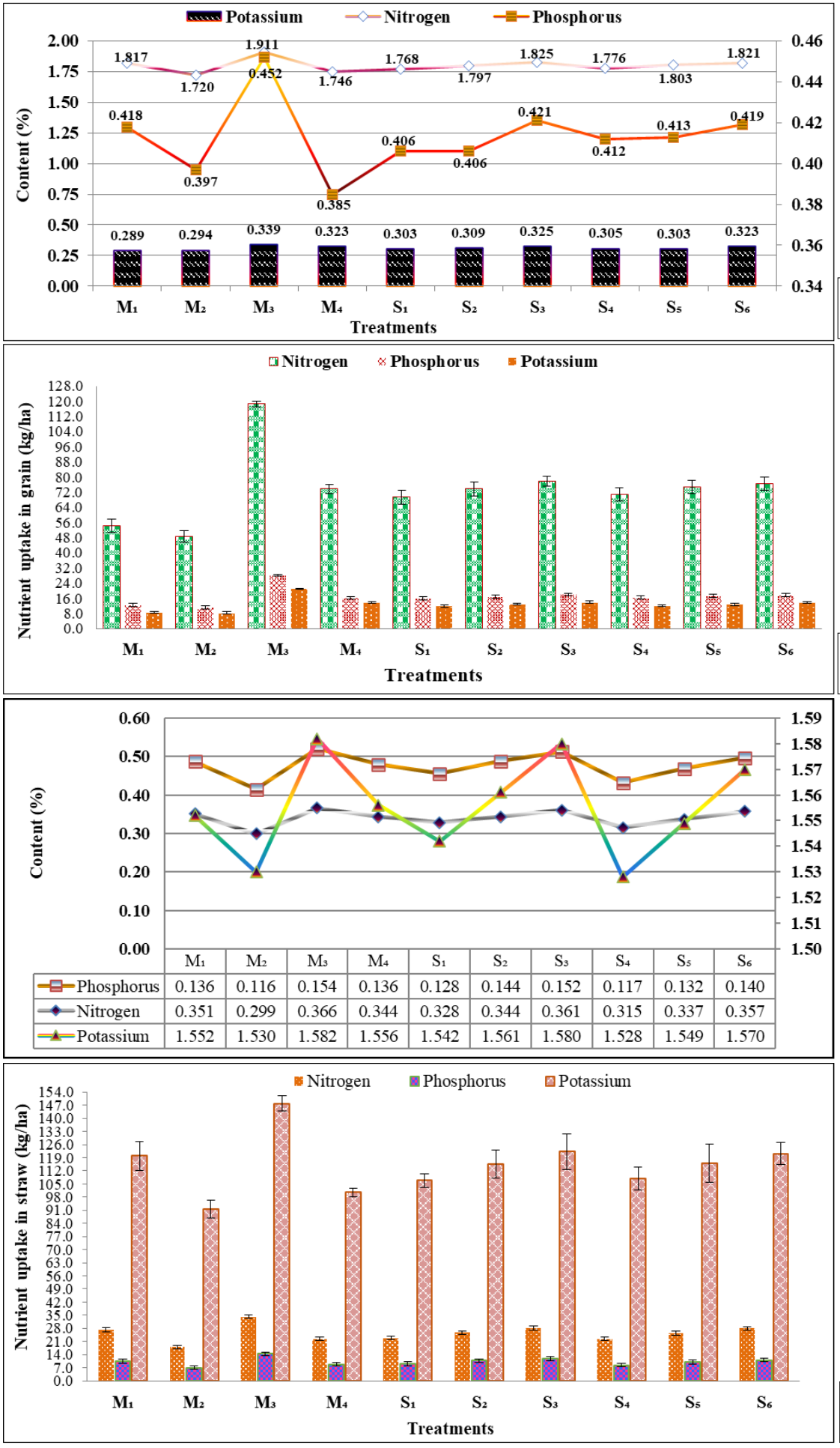

Fig. 3 (a, b, c, d). Impacts of various rates of seed and levels of fertilizer on nutrient contents and uptakes in grain and straw of dual-purpose wheat varieties.

more NPK content and uptake in grain was observed in WH 1105 as compared with C 306 variety during both years which might be due to genetic character of variety and because of lodging in tall wheat which resulted in less translocation of carbohydrates to sink.

Increasing level of fertilizer recorded higher NPK content and uptake in grain of wheat and it might be due to more availability of N which greatly helps the plant to expose its potential to grow vigorously. Thus, it led to an increased vegetative growth of crop and resulted in more LAI, therefore enhanced photosynthetic activity and more biomass production. NPK content at higher dose of fertilizer may be due to better activation of root system by optimum nutrition which efficiently helps in better absorption of nutrients from soil producing higher nutrient concentration.

Available NPK (kg/ha) after harvest

The effect of different seed and fertilizer levels on available NPK in soil after harvest of dual purpose tall and dwarf wheat during subsequent years are presented in Table 2. Significantly higher available NPK content of soil was observed in cut plots of WH 1105 variety as compared with no-cut plots with either seed rate during both the years of study, whereas, higher available NPK content of soil was observed in no cut plots of C 306 variety as compared with cut plots with either seed rate during both the years which might be due to lower uptake by this variety. Among both the varieties, more available NPK in soil was observed in WH 1105 as compared to C 306 variety during both years which might be due to lower nutrient uptake efficiency or slower utilization by WH 1105 as compared to C 306.

In case of seed rate and fertilizer combination treatments, significantly higher available NPK in soil was observed in wheat sown with 130 % RDF over wheat sown with 100 % RDF with either seed rate during both the years of study which might be due to direct relationship between higher dose and available NPK in soil. It is obvious that availability of nutrient is more at higher doses of fertilizers which might be due to the fact that more application of fertilizers enhances the nutrient status of soil.

Protein and crude protein yield in grain (kg/ha)

Significantly more protein and crude protein yield in grain of both the wheat varieties was observed in no-cut plots as compared with cut-plots with either seed rate during both the years of study and, it might be due to the absence of cutting shock with no interruption in normal plant growth under no-cut situation in (Fig. 4). Reduction in protein and crude protein yield in grain might be due to removal of photosynthetic organs by clipping which negatively affected the source sink relationship. In the case of varieties, more protein and crude protein yield in

Table 2. Impacts of various rates of seed and levels of fertilizer on available NPK after harvest (kg/ha) in soil (Pooled data of 2 years) in dual purpose wheat varieties

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
M_1	126.45	32.12	384.51
M_2	122.52	31.42	382.74
M_3	124.73	32.46	384.93
M_4	126.88	33.18	386.38
S.E m ±	0.05	0.03	0.18
C.D. at 5 %	0.19	0.11	0.63
S_1	124.46	31.68	383.33
S_2	125.45	32.57	385.47
S_3	127.47	34.64	388.14
S_4	122.87	30.53	381.13
S_5	124.61	31.28	383.45
S_6	126.02	33.09	386.33
S.E m ±	0.02	0.02	0.05
C.D. at 5 %	0.07	0.07	0.14

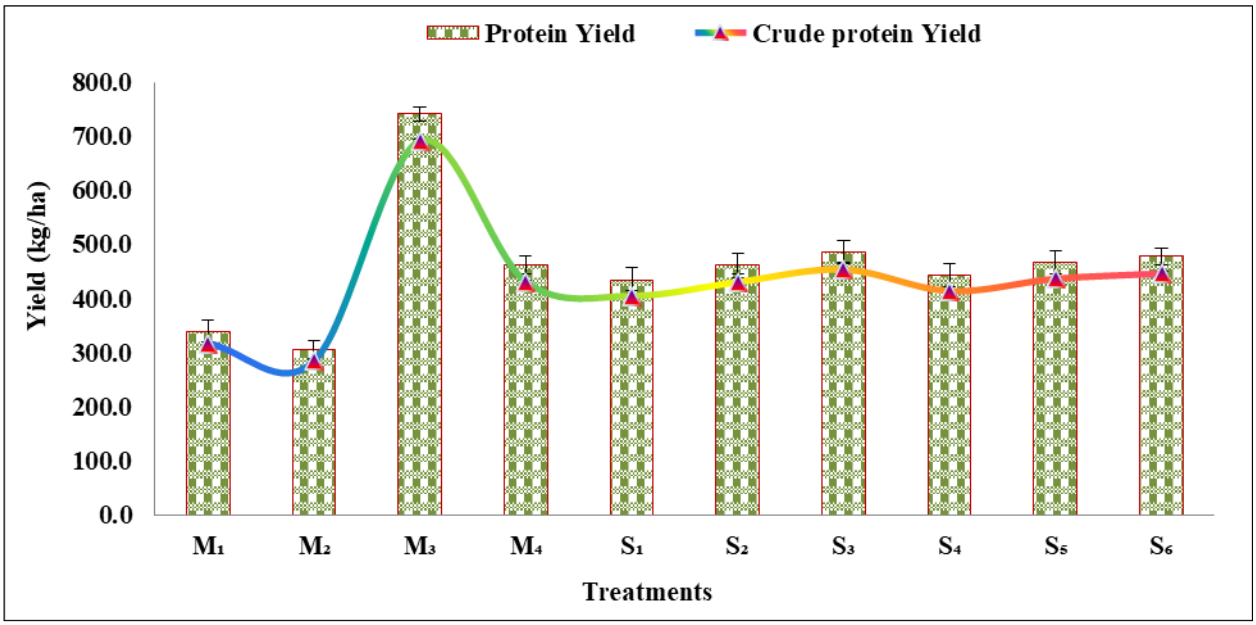

Fig. 4. Impacts of various rates of seed and levels of fertilizer on protein and crude protein content (pooled data of 2 years) in dual purpose wheat varieties.

grain was observed in WH 1105 as compared with C 306 variety during both the years. Significantly higher protein yield in grain was observed in WH 1105 variety (741.15 and 691.35 kg/ha) over C 306 variety (339.10 and 316.30 kg/ha) during both the years under without-cut plots.

In case of seed rate and fertilizer combination treatments, significantly higher protein and crude protein yield in grain was recorded in wheat sown with 130 % RDF over wheat sown with 115 % and 100 % RDF with either seed rate. Increasing level of fertilizer recorded higher protein and crude protein yield in grain of wheat while increasing seed rate recorded lower protein and crude protein yield in grain of wheat during both the years.

Quality parameters

Different wheat varieties did not show any significant variation in respect of quality parameters viz. sedimentation value, starch content and grain appearance (Table 3). However, in hectolitre weight both the varieties (both cuts and without cuts) was recorded significant and C 306 without cut was observed higher than the rest. Higher sedimentation value, starch content, grain appearance and hectolitre weight (35.45, 61.89 %, 6.46 and 81.5 kg/hL) were recorded in WH 1105 wheat variety as compared to C 306 it might be due to its superior genetic makeup and improved grain quality traits developed through breeding for high yield and better processing quality.

In case of seed rate and fertilizer combinations, significant values were observed in sedimentation and grain appearance and highest values recorded with S_6 (125 kg/ha seed rate with 130 % RDF) and lowest in S_1 (100 kg/ha seed rate with 100 % RDF) (36.55 and 6.31) whereas, starch content and hectolitre weight were not influence by the treatments and highest was recorded in S_6 (62.35 %, 82.9 kg/hL) and lowest in S_1 (61.21 % and 78.2 kg/hL).

Grain and straw yield (q/ha)

Significantly higher grain and straw yield of both the wheat varieties was observed in no-cut plots as compared with cut-plots with either seed rate presented in Fig. 5. It may be due to the fact that in no cut plots, there was higher value of plant height, leaf area and CGR which ultimately increased total biomass of plant and hence straw yield. Among varieties, significantly more loss in grain and straw yield due to cut (for green fodder) was observed in WH 1105 as compared to C 306. Results show the significantly grain yield by 108 from 62.03 to 29.79 q/ha and, straw yield by 20.8 % from 93.43 to 77.35 q/ha higher grain and straw yield respectively were observed in WH 1105 over C 306 under without cut condition during both the years which may be attributed to the lodging problem of C 306 variety due to its tallness. Significantly more loss in crop yield, particularly grain yield, due to cut (for green fodder) was observed in WH 1105 as compared to C 306 cultivar and it might be due to poor regeneration growth of WH 1105 as compared to C 306.

Table 3. Impacts of various rates of seed and levels of fertilizer on quality parameters (Pooled data of 2 years) in dual purpose wheat varieties

Treatments	Sedimentation value	Starch content (%)	Grain appearance	Hectolitre Weight (kg/hL)
M_1	34.17	61.63	5.97	79.9
M_2	33.82	61.39	6.23	78.2
M_3	35.45	61.89	6.46	81.5
M_4	34.39	61.48	6.13	80.9
S.E m ±	0.59	0.03	0.13	0.90
C.D. at 5 %	NS	NS	NS	3.00
S_1	31.53	61.21	6.00	78.2
S_2	34.27	61.27	6.13	81.2
S_3	35.85	62.29	6.29	82.0
S_4	34.20	61.25	6.27	80.8
S_5	34.40	61.23	6.18	81.6
S_6	36.53	62.35	6.31	82.9
S.E m ±	0.50	0.04	0.03	1.40
C.D. at 5 %	1.42	NS	0.08	NS

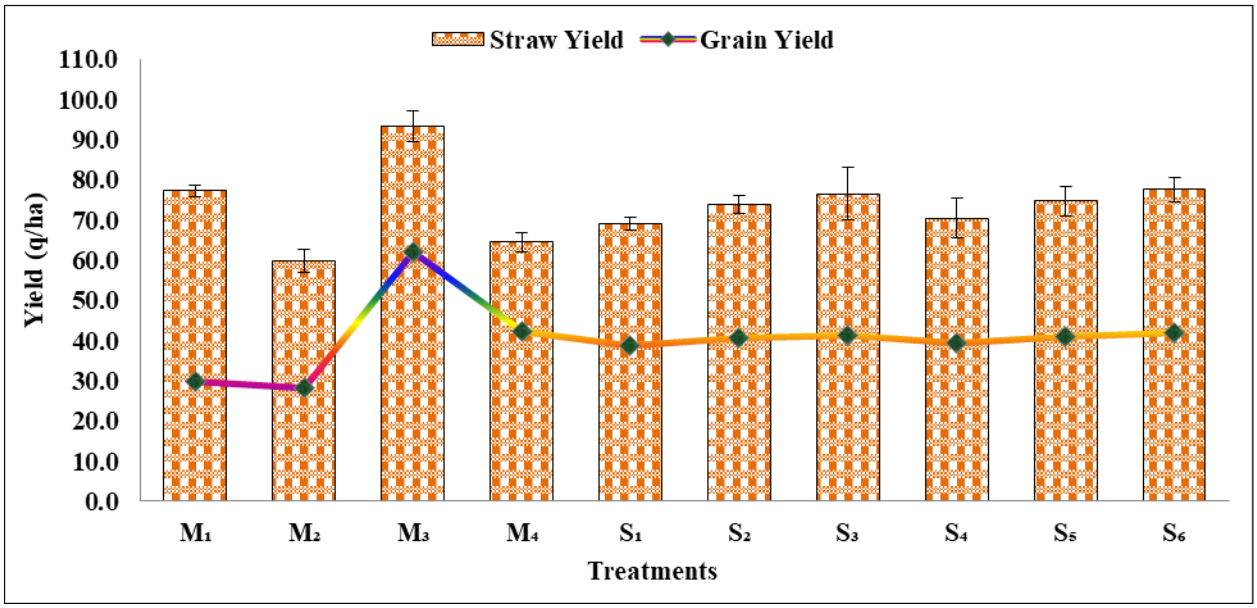

Fig. 5. Impacts of various rates of seed and levels of fertilizer at grain and straw production (Pooled data of 2 years) in dual purpose wheat varieties.

In case of seed rate and fertilizer combination treatments, significantly higher grain and biological yield was observed in wheat sown with 115 % RDF over wheat sown with 100 % RDF with either seed rate which remained significantly lower than 130 % RDF.

Principal component analysis

Due to a complex interactive effect among various growth, yield and quality parameters of dual-purpose wheat, the principal component exploration was performed to lower down the parsimony and dimensionality of the data (Fig. 6). The 2 principal components (PCs) were measured with eigenvalues $\geq$ 1.0, with normalization procedure of Kaiser after the rotation of varimax. Suggesting these principal component scores might be used to summarize the original 9 variables in any further analysis of the data. Out of the principal components (PC_1 and PC_2) were worked out and asserted a very high cumulative variance of 88.44 %. PC_1 explained 66 % while PC_2 explained 22.4 % of the total variance.

Correlation analysis

The data in Fig. 7 depicted correlation of grain yield with different growth parameters i.e. dry matter production and leaf area index, various yield characteristics i.e. number of functional tillers, length of spike, number of grains/spike, 1000 seed weight along with several quality parameters i.e. protein yield and crude protein yield. The results revealed that the grain yield was found in-significant with leaf area index.

Absolute Growth Rate (AGR)

Significantly highest value of absolute growth rate of observed in wheat sown at 125 kg/ha seed rate with 130 % RDF for the

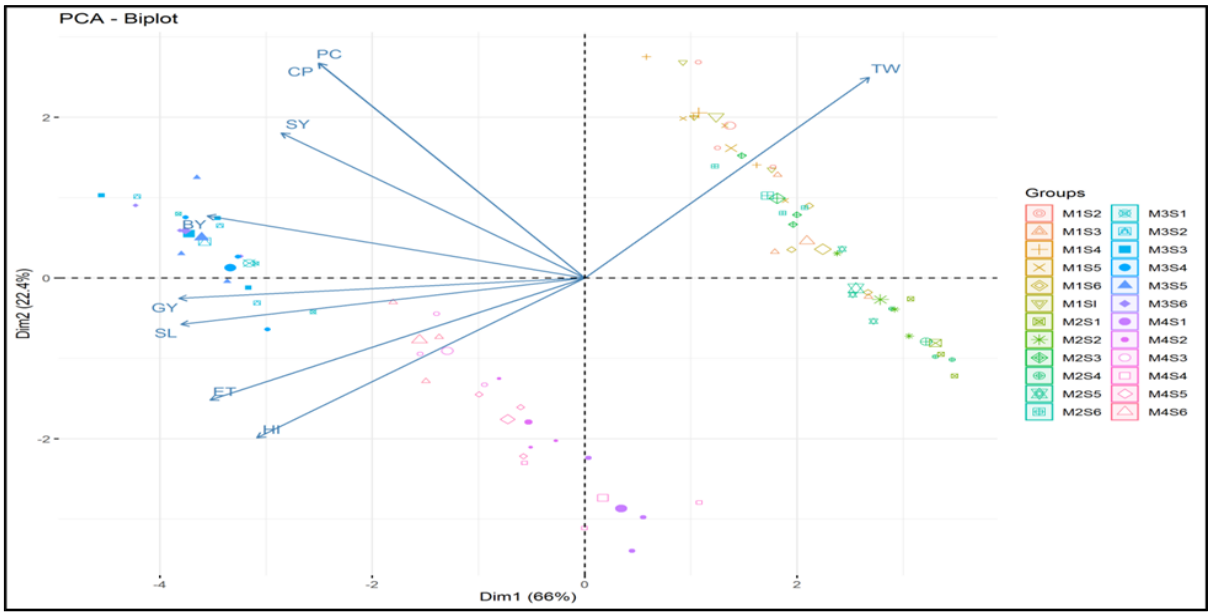

Fig. 6. Biplot graphical display of the measured parameters in dual purpose wheat cultivars.

HI- harvest index, ET-effective tillers, SL- spike length, GY- grain yield, BY- biological yield, SY- straw yield, PC- protein content, CP- crude protein and TW- test weight .

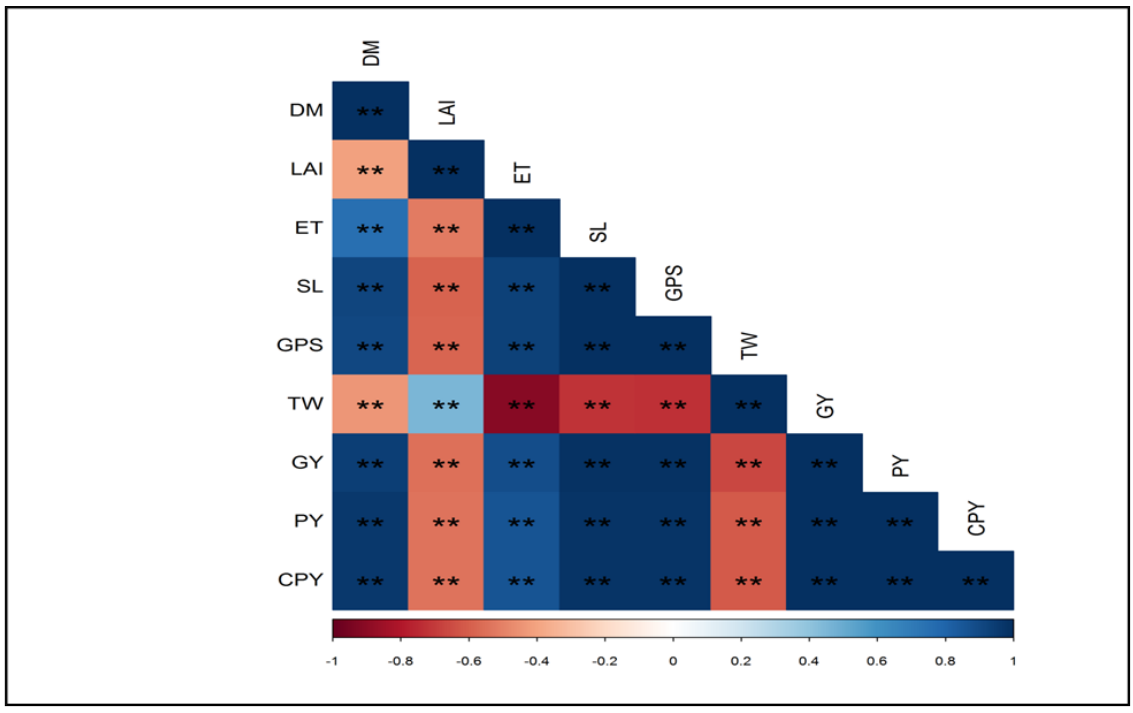

Fig. 7. Correlation of grain yield with growth parameters, yield attributes and quality parameters.

period of 0 to 30, 31 to 60, 61 to 90, 91 to 120 DAS and 121 DAS at harvesting respectively is mainly due to improvement in availability of nutrient with higher value of RDF and increase in the value of LAI with higher seed rate that leads to more photosynthetic efficiency and higher growth rate. These findings are in line with the previous studies (15, 16).

Nutrient content and uptake in grain and straw

Among C 306 and WH 1105 cultivars, greater uptake of nutrients and its content observed in grain and straw of no cut plots as compared with cut-plots with either seeding rate might be due to the absenteeism of cutting shock with normal plant growth under no-cut situation. Higher NPK content and uptake observed in WH 1105 as compared to C 306 cultivar may also be influenced by the genetic traits of the wheat variety or by lodging in taller plants, which led to reduced carbohydrate movement toward the sink tissues.

Increasing level of fertilizer recorded higher content and uptake of NPK in grain of wheat and it might be due to more availability of N which critically assists the plant to exploit its potential to grow dynamically. Thus, it led to an increased vegetative growth of crop and resulted in more LAI, therefore enhanced photosynthetic activity and more biomass production. Increasing level of fertilizer also recorded higher NPK content and uptake in straw of wheat and these findings are in line with earlier observations (17). Possible increase of content of NPK at higher dose of fertilizer may be due to more growth of root system in proper nutrient availability which competently improves the absorption of nutrients from soil containing plenty of available nutrients. These results confirm the results of previous studies (18). Increased seed rate recorded significantly more NPK uptake in wheat grain during both years and it might be due to increased biomass production whereas, increased seed rate recorded lower NPK content in wheat grain during both years which might be due to the fact that increase in plant population cause competition among the plants for limited nutrient and results into low nutrient uptake. These findings are in agreement with the earlier reports (19, 20).

Available NPK (kg/ha) after harvest

Among both the cultivars, higher value of NPK in soil observed in WH 1105 as compared with C 306 might be due the point that more quantity of nutrients was applied to WH 1105 as compared to C 306. In case of seed rate and fertilizer combination treatments, significantly higher available NPK content of soil observed under wheat sown with 130 % RDF over wheat sown with 100 % RDF may be due to the direct relationship between applications of higher fertilizer dose led to deposition of nutrient in the soil liable pool. Higher plant growth under this dose got higher growth and more root biomass that resulted in enhanced soil microbial activities and ultimately increased nutrient transformations and nutrient availability in the soil. It is obvious that availability of nutrient is more at higher doses of fertilizers which might be due to the fact that more application of fertilizers enhances the nutrient status of soil. These results are in collaboration with earlier findings (21). Higher seed rate resulted into lower NPK content in soil with lower fertilizer levels during both the years and it might be due more uptake of nutrients by more biomass production under higher seed rates.

Protein and crude protein content in grain (kg/ha)

Significantly more protein and crude protein content in grain of both the wheat cultivars observed under no-cut plots as compared with cut-plots with either seeding rate may be due to the absenteeism of cutting shock with no disruption in usual plant growth under no-cut situation. Reduction in protein and crude protein yield in grain might be due to deduction of photosynthetically active organs by clipping activity which adversely affected the relationship between source and sink. Similar findings were reported earlier (22, 23). Increasing level of fertilizer recorded higher protein and crude protein yield in grain of wheat while increasing seed rate recorded lower protein and crude protein yield in grain of wheat during both years. It might be due to the direct relationship between nitrogen and protein content (24).

Quality parameters

Higher sedimentation value, starch content, grain appearance and hectolitre weight were recorded in WH 1105 wheat variety as compared to C 306. This is in confirmation with the earlier findings (25). Significantly lower sedimentation value, starch content, grain appearance and hectolitre weight were observed in wheat sown at 100 kg/ha seed rate with 100 % RDF. Similarly, it was reported that hectolitre weight did not differ significantly affected by nitrogen rates but was responsive to phosphorus fertilizers where the highest rates (46 and 69 kg P_2O_5/ha) showed statistically similar and higher values than the control treatment (26).

Grain and straw production (q/ha)

Significantly higher grain as well as straw production of both the wheat cultivars reported in no-cut plots as compared with cut-plots with either seed rate may be due to the fact that in no cut plots, there is higher plant height, expanded leaf area and elevated crop growth rate (CGR) contributed to increased overall biomass, thereby enhancing straw yield. Across the varieties, WH 1105 consistently produced significantly higher grain and straw yields under the no-cut condition compared to C 306 in both the years. This difference is likely due to the lodging tendency of the taller C 306 plants. Among the cultivars, the impact of lodging was more pronounced in terms of crop yield reduction, especially affecting grain yield cutting shock (for fodder) was observed in WH 1105 as compared with C 306 cultivar which might be due to poor regeneration growth of WH 1105 as compared to C 306. Higher N content has a positive effect on dry matter production of wheat crop (27). Similarly, higher seed rate of wheat also resulted into greater yield of wheat.

Principal component analysis

As mentioned in results, 2 principal components (PCs) were analysed with eigenvalues $\geq$ 1.0, with normalization procedure of Kaiser after rotation of varimax, so these principle component scores are used for further analysis of the data. A very high cumulative variance was explained by PC_1 whereas PC_2 explained moderate variance. Reports are also on the extraction of 2 PCs which together explained a cumulative variance of 92 % of the variation among yield characteristics, with highest proportion of contribution by grain yield q/ha attribute among 9 attributes followed by number of grains/spike (28).

Correlation analysis

The in-significant relationship of grain yield with leaf area index might be due to lodging of wheat plants which is a big problem in tall wheat and leads to less translocation of carbohydrates to sink and thus reduced grain yield. The decline in grain production due to increase in leaf area index was also observed (29). The negative correlation of test weight with grains/spike might be due to the concept that test weight was also negatively correlated with number of grains per spike, however, other parameters are highly positively correlated with grain yield and similar results were observed in earlier studies (29, 30), i.e. tillers per plant, spike length and number of grains/spike etc. which were determined to have direct effects on grain yield and positively correlated with grain yield.

Conclusion

Cut management practices were found to negatively impact grain yield, reduce protein and crude protein content in wheat. However, the nutritional value of the resulting fodder still benefits livestock. The tall wheat variety C 306 exhibited a lower absolute growth rate compared to the dwarf variety WH 1105, primarily due to its limited responsiveness to inputs like fertilizer and irrigation, which is attributed to lodging issues. Among various seed rates and fertilizer levels, wheat sown with 130 % RDF consistently produced higher grain and straw yields, along with increased protein and crude protein content, compared to 115 % and 100 % RDF at any seed rate. Based on the experimental results, C 306 sown at 100 kg/ha with 115 % RDF in irrigated conditions appears suitable for dual-purpose cultivation-providing both fodder (cut at 60 DAS at 5 cm height) and grain.

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Authors' contributions

HD supervised the manuscript, participated in the sequence alignment and drafted the manuscript. VSH prepared completed the writing work and reviewing the collected data. DKJ and AS collected the literature and review and make the suitable correction. PD visualized the data and written content. AY made the proper data curation. RD analysed and interpreted the data with software. SK format the manuscript in proper manner. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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