International Journal of Plant & Soil Science

Volume 35, Issue 18, Page 66-73, 2023; Article no.IJPSS.101524
ISSN: 2320-7035

Response of Nitrogen and Plant Growth Regulators on Growth and Yield of Wheat (*Triticum aestivum* L.)

Malkarnekar Saharsh [a++*], Rajesh Singh [a#] and Thakur Indu [a†]

[a] *Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj–211007, Uttar Pradesh, India.*

Authors' contributions

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

Article Information

DOI: 10.9734/IJPSS/2023/v35i183267

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101524

Original Research Article

Received: 22/04/2023
Accepted: 26/06/2023
Published: 14/07/2023

ABSTRACT

A research trial was conducted during *Rabi* season, 2022 at crop research farm, Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj Uttar Pradesh India. The soil in experimental field was sandy loam in texture, having alkaline reaction (pH 7.7) with very low organic carbon (0.44%), available higher-level N (171.48 kg/ha), P (27.0 kg/ha) and higher level of K (291.2 kg/ha). To evaluate the response of nitrogen and different plant growth regulators on growth and yield of wheat (*Triticum aestivum*) the experiment was laid out in Randomized Block Design (RBD) with ten treatments each replicated thrice. The treatment consists three levels of nitrogen (120 kg/ha, 140 kg/ha and 160 kg/ha), in combination with two sprays of Plant growth regulators *viz*. [Chlormequat chloride (0.2%), Tebuconazole (0.1%) and chlormequat chloride (0.2%) + tebuconazole (0.1%)] applied at 40 DAS followed at 55 DAS whose

---

[++] *M.Sc. Scholar;*
[#] *Associate professor;*
[†] *PhD Scholar;*
**Corresponding author: E-mail: malkarnekarsaharsh28@gmail.com;*

effect was observed on wheat. The results revealed that, higher plant height (98.70 cm), was recorded with treatment nitrogen 160 kg/ha along with Tebuconazole (0.1%). However, maximum number of tillers/running row meter (78.33), maximum dry weight (23.01 g), higher crop growth rate (0.0059 g/m^2/day), more number of effective tillers/m^2 (271), highest spike length (15.10 cm), maximum number of grains/spike (60.05), higher test weight (39.75 g), maximum grain yield (4.66 t/ha),) and straw yield (6.98 t/ha) were recorded with treatment nitrogen -160 kg/ha along with CCC (0.2%) and Tebuconazole (0.1 %) in wheat. Application of both nitrogen and plant growth regulators improved the growth and yield of wheat significantly.

Keywords: Nitrogen; plant growth regulator; chlormequat chloride; tebuconazole; growth and yield.

1. INTRODUCTION

"Worldwide, wheat (*Triticum aestivum* L.) being a staple food for large population contributing about 20% of humans' daily dietary calorie and protein intake" Shiferaw et al. [1]. "Wheat is the second most important food grain of India with an area of 30.5 million hectare, production of 98.4 million tonns, and an average productivity of 3216 kg/ha" (Anonymous 2016). "Rajasthan is one of the major wheat growing state in India with an area of 3.11 million hectare (10.3% area of country), 9.90 million tonns of production (10.6% production share at the national level), and productivity of 3175 kg/ha" (Anonymous 2016). "Lodging, usually characterized by permanent displacement of stems from an upright position due to internal and external factors, is an important constraint limiting wheat yields and quality in both developed and developing countries" Berry et al. [2].

"Nitrogen is considered as most important fertilizer element determining the productivity of wheat. Higher wheat yields realized by applying greater doses of N fertilizers due to improved lodging resistance, resulting from short-stiff straw, is moderately expressed at moderate nitrogen levels. However, even spring wheat cultivars carrying Norin 10 dwarfing genes have been reported to lodge" Narang et al. [3]. "Application of N at higher rates decreases breaking strength of the 2nd internode, decreases stem strength leading to increased lodging and decreased wheat yields and its components". Narang et al. [3].

"Growth retardants are chemical substances that have the potential to alter structural or vital processes inside the plant by modifying hormone balance to increase yield, improve quality or facilitate harvesting through checking lodging especially in cereals" Zhang et al. [4]. "Lodging preventers (plant height retardants) are generally antagonistic to gibberellin and act by altering their metabolism and for aforesaid reason they are frequently called anti-gibberellin". Peake et al. [5] "The nature and extent of lodging are closely related to height of the stem, which can be modified by application of growth inhibitors" Peng et al. [6]. "Application of growth inhibitors, like ethephon (2-chloro ethyl phosphonic acid) or CCC (Chlormequat Chloride), was reported to be useful in decreasing plant height and subsequently reducing lodging" Niu et al. [7], Pitre et al. [8]. Therefore, the objective of present study was to determine the effects of different fertility practices and lodging preventers on growth behavior, productivity and farm profitability of wheat under semi-arid conditions.

2. MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season, 2022 at Central Crop Research Farm, Department of Agronomy, SHUATS Prayagraj, Uttar Pradesh. The soil in experimental field was sandy loam texture, having alkaline reaction (pH 7.7) with very low organic carbon (0.44%), available higher N (171.48 kg/ha), P (27.0 kg/ha) and higher level of K (291.2 kg/ha). The experiment was conducted in Randomized Block Design (RBD) consist three levels of nitrogen (120 kg/ha, 140 kg/ha and 160 kg/ha), in combination with two sprays of Plant growth regulators *viz*. [Chlormequat chloride (0.2%), Tebuconazole (0.1%) and chlormequat chloride (0.2%) + tebuconazole (0.1%)] and control. There were ten treatments each replicated thrice. The biometric observations were recorded at various stages of crop growth on different characteristics *viz*., plant height (cm), number of tillers/running row meter, plant dry weight (g) and crop growth rate (g/m^2/day) on five plants randomly selected from each net plot.

Post harvest studies include number of effective tillers/m^2, spike length (cm), number of grains/spike, test weight (g), grain yield (t/ha), straw yield (t/ha) and harvest index (%) were also calculated.

List 1. Treatment combinations

Treatment Number	Treatment Details	
T_1	1.	N_1- 120 kg/ha + CCC (Chlormequat chloride) - 0.2%
T_2	2.	N_2-140 kg/ha + CCC (Chlormequat chloride) - 0.2%
T_3	3.	N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2%
T_4	4.	N_1- 120 kg/ha + Tebuconazole - 0.1%
T_5	5.	N_2-140 kg/ha + Tebuconazole - 0.1%
T_6	6.	N_3 -160 kg/ha + Tebuconazole - 0.1%
T_7	7.	N_1- 120 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)
T_8	8.	N_2-140 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)
T_9	9.	N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)
T_{10}	10.	Control (150-60-40 NPK kg/ha)

Plant Height (cm): The average height of plants was recorded at an interval of 25 DAS. The height of plant was measured from the base of the plant up to the tip. Height of the plants was recorded at 25, 50, 75 and 100 days after sowing and five plants were randomly selected from each plot which was tagged for observations.

Number of Tillers/Running Row Meter: The number of tillers was counted per metre row length from third row on either side in each plot, representing the whole plot, at 25, 50, 75 and 100 DAS.

Plant Dry Weight (g): Dry weight of plants was recorded at 25, 50, 75, and 100 DAS, for taking this observation five plants were uprooted randomly from each plot. The uprooted plants were sun-dried and kept in oven for drying at 110^{O} F temperature. After 2-3 days, when the plants were dried completely, the weight was recorded.

Number of Effective Tillers per m^2: Grains bearing tillers was counted in one meter square at harvesting stage. The crop of one square meter area from the center of each plot was harvested and count the number of effective tillers.

Spike Length (cm): Five representative spikes were harvested from marked rows. The spike length (cm) was measured from the base of the peduncle (lower spikelet) to the tip of the top spikelet.

Number of Grains per Spike: From the spikes selected for measuring spike length, the grains were separated from spikelet and the grains were counted and the grains per spike were worked out.

Test Weight (g): A random sample of 1000 seeds was taken from the harvested bulk and was weighed.

Grain Yield (t/ha): Seed yield from the harvest area (1.0 m^2) were dried in sun, cleaned and weighed separately from each plot for calculating the seed yield in t/ha.

Straw Yield (t/ha): Straw yield was calculated by subtracting grain yield from biological yield for each of net plot area and expressed in (t/ha).

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

3.1.1 Plant height (cm)

The fertility practices had significant effect on plant height of wheat at all the growth stages. At 100 DAS, higher plant height (98.70 cm) was recorded in treatment 6 with application of N_3 - 160 kg/ha + Tebuconazole - 0.1% as compared with other treatments, followed by treatment 3 (97.03 cm) with application of N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2%. This is because the retardant effects of plant growth regulators result in a significant reduction in plant height throughout the growing season, even with a higher nitrogen intake. Rajala et al. [9] and Kesarwani et al. (2018) discovered similar results. “Application of double PGRs enabled the plant for reduction of plant height over single PGRs. This might be due to Chloremequat chloride inhibits gibberellin biosynthesis via blocking ent-kaurene synthesis in the metabolic pathway of gibberellin production, resulting in reduced amounts of active gibberellins and consequent reduction in stem elongation” Anosheh et al. [10].

3.1.2 Number of tillers/running row metre

At 100 DAS, the data revealed that maximum number of tillers/running row meter (78.33) was recorded in treatment 9 with application of N_3 - 160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). Treatment 6 with application of N_3 -160 kg/ha + Tebuconazole - 0.1% (72) were statistically at par with treatment 9 [N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)]. Similar findings were reported by Rodrigues et al. [11].

“The increase in tiller production was probably because of greater supply of nitrogen to be used for cell multiplication and enlargement and also for the formation nucleic acid and other vitally important compounds in the cell sap” [12] [Gouping et al. (2002)].

3.1.3 Plant dry weight (g)

At 100 DAS, maximum plant dry weight (23.01 g) was recorded in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%) followed by treatment 6 [N_3 -160 kg/ha + Tebuconazole - 0.1% (22.02 g)] and treatment 3 [N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2% (21.68 g)]. “Since, the major nutrient (nitrogen) are known as important constituents for cell division and cell elongation and their optimum availability with integrated use of organic and inorganic nutrient sources led to higher plant growth. Higher availability of these nutrients might improve photosynthetic area of plants that cumulatively contribute to higher dry matter accumulation”. [13,14,15].

“The highest dry weight was recorded in the maturity stage due to the mass accumulation of the crop and also the dry weight increased with application of plant growth regulator, might be due to the better growth of healthy seedlings” Kumar and Yadav (2005).

3.1.4 Crop growth rate (g/m^2/day)

During 50-75 DAS maximum crop growth rate (0.0059 g/m^2/day) was recorded in treatment 9 with application of N_3-160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). However, crop growth rate (0.0054 g/m^2/day) in treatment 6 and crop growth rate (0.0051 g/m^2/day) in treatment 8 was statistically at par with treatment 9 [N_3-160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)].

3.2 Post Harvest Observation

3.2.1 Number of effective tillers/m^2

Number of effective tillers/m^2 showed difference among all treatments. Whereas, maximum number of effective tillers/m^2 (271) was observed in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). However, number of effective tillers/m^2 (257) of treatment 3 with application of N_3 -160 kg/ha CCC (Chlormequat chloride) - 0.2%, was found to be statistically at par with treatment 9.

“Cycocel which is most widely used in wheat stimulates tillering, redistributes biomass with increased root growth, and reduces plant height and increase stiffness of straw that reduces the risk of lodging. The success of cycocel on wheat crop has been reported at commercial scale in many countries, especially under assured irrigation facilities and under high fertility” Kaur et al. [16].

3.2.2 Spike length (cm)

Spike length showed significant difference among all treatments however, highest spike length (15.10 cm) was observed in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). Whereas, spike length (13.83 cm) of treatment 6 with application of N_3 -160 kg/ha + Tebuconazole - 0.1% was found to be statistically at par with highest Hussain et al. [17] and Ahmad et al. [18]. They concluded that spike length of wheat increased significantly with increasing nitrogen levels.

3.2.3 Number of grains/spike

Maximum number of grains/spike (60.05) was observed in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). Followed by treatment 6 (54.66) grains/spike with application of N_3 -160 kg/ha + Tebuconazole (0.1%). Ali et al. [19] observed that number of grains/spike, 1000 grain weight and grain yield were significantly increased by increasing the nitrogen level over control. Among nitrogen levels, highest grain yield was obtained by an application of nitrogen 180 kg/ha.

3.2.4 Test weight (g)

The growth regulators led significant effect on test weight and the maximum values were recorded with the combined application of CCC + Tebuconazole. Higher test weight (39.75 g) was recorded in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%) followed by treatment 3 (39.21 g) with application of N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2%. Similar results on wheat with the use of plant growth retardants were also reported by Guoping et al. [20] and Rajala et al. [9].

Table 1. Response of nitrogen and plant growth regulators on growth parameters of wheat

Sr. No.	Treatment combinations	Plant height at 100 DAS	Number of tillers/running row meter 100 DAS	Dry weight (g) at 100 DAS	CGR(g/m^2/day) 50-75 DAS
1	N_1- 120 kg/ha +CCC (Chlormequat chloride) - 0.2%	83.07	61.00	18.24	0.0038
2	N_2-140 kg/ha + CCC (Chlormequat chloride) - 0.2%	90.60	69.00	18.76	0.0046
3	N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2%	97.03	67.67	21.68	0.0037
4	N_1- 120 kg/ha + Tebuconazole - 0.1%	85.21	62.67	19.19	0.0042
5	N_2-140 kg/ha + Tebuconazole - 0.1%	91.72	66.67	20.77	0.0033
6	N_3 -160 kg/ha + Tebuconazole - 0.1%	98.70	72.00	22.02	0.0054
7	N_1- 120 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	81.83	65.00	19.22	0.0042
8	N_2-140 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	88.68	70.00	21.14	0.0051
9	N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	95.17	78.33	23.01	0.0059
10	Control (150-60-40) NPK Kg/ha	83.79	62.00	18.56	0.0041
	F-test	S	S	S	S
	SEm(±)	2.86	2.19	0.74	0.0003
	CD (p=0.05)	8.50	6.51	2.20	0.0009

Table 2. Response of nitrogen and plant growth regulators on yield attributes and yield of wheat

Sr.No.	Treatment combinations	Number of effective tillers/m^2	Spike length (cm)	Number of grains/spike	Test weight (g)	Grain Yield (t/ha)	Straw Yield (t/ha)
1	N_1- 120 kg/ha + CCC (Chlormequat chloride) - 0.2%	219	10.60	43.89	36.07	3.78	5.82
2	N_2-140 kg/ha + CCC (Chlormequat chloride) - 0.2%	256	12.43	49.50	35.50	4.04	6.02
3	N_3 -160 kg/ha + CCC (Chlormequat chloride) - 0.2%	257	13.29	52.33	39.21	4.15	6.14
4	N_1- 120 kg/ha + Tebuconazole - 0.1%	243	9.97	49.00	36.20	3.63	5.74
5	N_2-140 kg/ha + Tebuconazole - 0.1%	251	12.00	52.00	37.28	4.14	6.27
6	N_3 -160 kg/ha + Tebuconazole - 0.1%	255	13.83	54.66	39.01	4.17	6.71
7	N_1- 120 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	239	11.10	47.84	36.47	3.98	5.89
8	N_2-140 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	242	13.00	50.00	37.38	4.28	6.40
9	N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%)	271	15.10	60.05	39.75	4.66	6.98
10	Control (150-60-40) NPK Kg/ha	234	9.47	43.35	33.77	3.68	5.63
	F-test	S	S	S	S	S	S
	Sem (±)	7.62	0.56	1.68	1.12	0.13	0.25
	CD (p=0.05)	22.63	1.68	5.0	3.34	0.38	0.73

3.2.5 Grain yield (t/ha)

Higher grain yield (4.66 t/ha) of wheat was found in treatment 9 with application of N_3 -160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%) which was superior over all other treatments, followed by treatment 8 (4.28 t/ha) with application of N_2 - 140 kg/ha + CCC (0.2%) + Tebuconazole (0.1%). However, the minimum grain yield (3.63 t/ha) was observed in treatment 4. "This might be due to increase the fertility levels which results more easily nutrients availability to the crop that results improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth and yield attributes of the crops probably due to more absorption and utilization of available nutrients leading to overall improvement of crop growth reflected to source-sink relationship, which in turn enhanced the yield attributes that ultimately more yield" Paul et al. [21].

3.2.6 Straw yield (t/ha)

Growth regulators were influenced significant effect on straw yield, maximum straw yield (6.98 t/ha) was recorded in treatment 9 with application of N_3 - 160 kg/ha + CCC (0.2%) + Tebuconazole (0.1%), followed by treatment 6 (6.71 t/ha) with application of N_3 -160 kg/ha + Tebuconazole – (0.1%) were statistically at par with highest. These results are in close agreement with the results of earlier researchers Tripathi et al. [22].

4. CONCLUSION

On the basis of summarized results, it is concluded that for better crop growth and higher yield , use of higher dose of nitrogen 160 kg/ha along with Plant Growth Regulators *viz*., Chlormequat chloride - 0.2% in combination with Tebuconazole - 0.1% sprayed at 40 and 55 days after sowing is most appropriate for wheat cultivation.

ACKNOWLEDGEMENT

With sincerity and immense pleasure, I feel great pride and privilege to express profound sense of gratitude and heartiest indebtedness to my esteemed advisor Dr. Rajesh for constant support, guidance and valuable suggestions for improving the quality of this research work and to all the faculty members of Department of Agronomy, SHUATS, Prayagraj, Uttar Pradesh for providing all necessary facilities, their cooperation, encouragement and support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Shiferaw B, Smale M, Braun H J, Duveiller E, Reynolds M, Muricho G. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Food Security. 2013;5(3):291–317.
2. Berry PM, Sterling M, Baker CJ, Spink J, Sparkes DL. A calibrated model of wheat lodging compared with field measurements. Agricultural and Forest Meteorology. 2003;119(3):167–80.
3. Narang RS, Tiwana US, Dev G. Maximum yield research studies in rice wheat system and soil productivity. The Indian experience in: Proceedings of the Transactions of 15th World Congress of Soil Science, Satellite Symposium ID-5 Research for Maximum Yield in Harmony with Nature, Acapulco, Mexico. 1994;46-57.
4. Zhang M, Wang H, Yi Y, Ding J, Zhu M, Li C, Guo W, Feng C and Zhu X. Effect of nitrogen levels and nitrogen ratios on lodging resistance and yield potential of winter wheat (*Triticum aestivum* L.). Plos ONE. 2017;12(11):45–9.
5. Peake AS, Huth NI, Carberry PS, Raine SR, Smith RJ. Quantifying potential yield and lodging-related yield gaps for irrigated spring wheat in sub-tropical Australia. Field Crops Research. 2014;158(2):1–14.
6. Peng D, Chen X, Yin Y, Lu K, Yang W, Tang Y and Wang Z. Lodging resistance of winter wheat (*Triticum aestivum* L.): Lignin accumulation and its related enzymes activities due to the application of paclobutrazol or gibberellin acid. Field Crops Research. 2014;157:1–7.
7. Niu LY, Feng S W, Ru ZG, Li G, Zhang ZP, Wang ZW. Rapid determination of single-stalk and population lodging resistance strengths and an assessment of the stem lodging wind speeds for winter wheat. Field Crops Research. 2012; 139(1):1–8.
8. Pitre F, Cooke J, Mackay J. Short-term effects of nitrogen availability on wood formation and fibre properties in hybrid poplar. Trees Structure and Function. 2007;21:249–59.

9. Rajala A, Peltonen-Sainio P, Onnela M and Jackson M. Effects of applying stem-shortening plant growth regulators to leaves on root elongation by seedlings of wheat, oat and barley: Mediatizon by ethylene. Plant Growth Regulation. 2002;38(1):51–9.
10. Anosheh HP, Emam Y, Khaliq A. Response of cereals to cycocel application. Iran Agricultural Research. 2016;35(1):1-12.
11. Rodrigues O, Didonet AD, Teixeira MCC, Roman ES. Growth Retardants. Passo Fundo: Embrapa Wheat Press; 2003.
12. Zhang GP. Gibberellic Acids3 modifies some growth and physiological effects of Paclobutrazol (PP333) on wheat. Journal of Plant Growth Regulation. 1997;16: 21-25.
13. Fliessbach A, Oberholzer HR, Gunst L, Mader P. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture Ecosystem and Environment. 2007;118:273–84.
14. Joergensen RG, Mäder P, Fliessbach A. Long-term effects of organic farming on fungal and bacterial residues in relation to microbial energy metabolism. Biology and Fertility of Soil. 2010;46:303–7.
15. Leifeld J, Reiser R, Oberholzer HR. Consequences of conventional versus organic farming on soil carbon: results from a 27-year field experiment. Agronomy Journal. 2009;101:1204–18.
16. Kaur R, Singh K, Deol JS, Dass A, Choudhary AK. Possibilities of improving performance of direct seeded rice using plant growth regulators: A review. Proc. National Academy of Sciences, India Section B: Biological Sciences. 2015;85(4):909-922.
17. Hussain S, Sajjad A, Hussain MI, Saleem M. Growth and yield response of three wheat varieties to different seeding densities. International Journal of Agriculture and Biology. 2001;3:228-229.
18. Ahmad MM, Yousaf N, Zamir MS. Response of wheat growth, yield and quality to varying application of nitrogen and phosphorous. Journal of Agricultural Research. 2000;38:28 9-29.
19. Ali A, Ahmad A, Syed WH, Khaliq T, Asif M, Aziz M, Mubeen M. Effect of nitrogen on growth and yield component of wheat. Science International. 2011;23(4):331-332.
20. Guoping Z, Jianxing C and Bull DA. The effects of timing of N application and plant growth regulators on morphogenesis and yield formation in wheat. Plant Growth Regulation. 2001;35: 239–45.
21. Paul J, Choudhary AK, Sharma S, Savita BM, Dixit AK, Kumar P. Potato production through bio-resources: Long-term effects on tuber productivity, quality, carbon sequestration and soil health in temperate Himalayas. Scientia Horticulturae. 2016;213:152-163.
22. Tripathi SC, Sayre KD, Kaul JN and Narang RS. Growth and morphology of spring wheat (*Z* L.) culms and their association with lodging: effects of genotypes, N levels and ethephon. Field Crops Research. 2003;84(3):271–90.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101524