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# Impact of nutrient management practices and plant growth regulators on growth, productivity and profitability of wheat (*Triticum aestivum*)

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## ABSTRACT

This study was conducted during winter season of 2016-17 and 2017-18 at Rajasthan Agricultural Research Institute, Durgapura, Jaipur to evaluate the effect of nutrient management and growth retardants on wheat (*Triticum aestivum* L.). Results revealed that the application of 150% RDF+FYM led to higher plant height and dry matter accumulation of wheat at all the growth stages (60 days after sowing (DAS), 90 DAS and at harvest) except at 30 DAS (where it was maximum with 150% RDF). The combined application of Chlormequat Chloride (CCC)+Tebuconazole reduced the plant height of wheat by 4.62, 2.25 and 2.86% (60 DAS), 7.07, 2.24 and 3.05% (90 DAS) and 7.35, 2.76 and 4.11% (at harvest) over water spray, CCC and Tebuconazole alone, respectively. The significantly maximum number of effective tillers (423.42 $m^{-2}$), spike length (10.66 cm) and test weight (40.32 g) were registered with application of 150% RDF+FYM. The combined spray of CCC+Tebuconazole enhanced the test weight by 7.71%, 2.63 and 2.84% over water spray, CCC and Tebuconazole, respectively. The significantly maximum grain, straw and biomass yield of wheat were recorded with 150% RDF+FYM which were 50.87, 50.31 and 50.56% and 12.26, 15.92% and 14.27% higher over control and 100% RDF, respectively. The grain, straw and biomass yields of wheat due to different growth retardant treatments were found statistically at par. The application of 150% RDF+ FYM increased the gross return by 50.74, 13.10 and 3.83% and mean net returns by 60.56, 12.96 and 3.13% over control, 100% RDF and 150% RDF, respectively. Among growth regulators highest net returns (₹ 68016) and B:C ratio (1.98) were recorded with combined application of CCC+Tebuconazole. It is concluded that integrated nutrient management using 150% RDF+FYM and combined application of CCC+Tebuconazole can be advocated as sustainable strategy for enhancing productivity and profitability of wheat.

**Key words:** Farm Profitability, Nutrient management, Plant growth regulators, Productivity and Wheat

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.* 2013). Wheat is the second most important food grain of India with an area of 30.5M ha, production of 98.4 M tonnes, and an average productivity of 3216 kg $ha^{-1}$ (Anonymous 2016). Rajasthan is one of the major wheat growing state in India with an area of 3.11 M ha (10.3% area of country), 9.90 M tonnes of production (10.6% production share at the national level), and productivity of 3175 kg $ha^{-1}$ (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.* 2003). The key reasons responsible for wheat lodging are increase in weight of mature ears due to water accumulation, occurrence of high speed winds at grain filling stage, wide use of flat planting and flood irrigation and the lack of acceptable cultivars of wheat that are lodging tolerant at higher nitrogen (N) rates etc. (Taiz and Zeiger 2004, Stachecki *et al.* 2004).

The lodging in wheat can be controlled by using short lodging tolerant cultivars and by applying growth retardant chemicals etc. (Rodrigues *et al.* 2003).The semi-dwarf wheat cultivars can limit lodging under moderate levels of inputs, especially fertilizer and irrigation. Lodging resistance of these improved semi dwarf cultivars, resulting from shorter and stiffer straw, is markedly expressed at moderate levels of N fertility (Pinthus 1974). Under certain agronomic conditions, however, even semi dwarf wheat cultivars have been observed to lodge under Indian condition (Tripathi *et al.* 2003). This form of lodging which is most common with well-managed wheat crop occurs near or after flowering

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and is primarily the result of wind during or soon after irrigation or rainstorms (Hobbs 2007). The reduction in grain yield caused by lodging ranged from 7 to 35% with greatest effect when lodging occurred within the month after anthesis, is most commonly reported under Indian condition. The yield potential of high yielding genotypes of wheat under irrigated and high input rates could be achieved consistently and efficiently by finding suitable solutions of lodging problem. In this context, the use of growth retardants found to be most effective for managing the problem of lodging (Zhang *et al.* 2017) and realizing productivity potential especially under high fertilization conditions (Rajala *et al.* 2002, Tripathi *et al.* 2003).

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.* 2017). Lodging preventers (plant height retardants) are generally antagonistic to gibberellin and act by altering their metabolism (Peake *et al.* 2014) and for aforesaid reason they are frequently called anti-gibberellin. 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.* 2014). 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.* 2012, Pitre *et al.* 2007).Therefore, the objective of present study was to determine the effects of different fertility practices and lodging preventers on growth behaviour, productivity and farm profitability of wheat under semi-arid conditions.

## MATERIALS AND METHODS

The field experiment was conducted during two consecutive winter season of 2016-17 and 2017-18 at research farm of the institute under All India Coordinated Wheat and Barley Improvement Project to examine effect of fertility levels and growth retardants on growth, productivity and economics of wheat.The experimental site falls in the Semi-Arid Eastern Plain Zone of Rajasthan (III-A), characterized by cold winters and hot summers. Occurrence of frost (below 0°C) during December/ January in winter season is quite common. The average annual rainfall of zone is 525 mm of which about 90% is received during later half of June to September with erratic distribution over time and space. The soil of the experimental field was loamy sand in texture having pH of 7.9, low in organic carbon and nitrogen, medium in available phosphorus and potassium. The experiment was laid out in split plot design and consist of four fertility levels, viz. Control (No fertilization) , 100% RDF (Recommended dose of fertilizer: 150:60:40 kg/ha), 150% RDF (225:90:60 kg/ha) and 150% RDF (225:90:60 kg/ha)+15t FYM/ha in main plots and four plant growth regulators, viz. control (water spray), 0.2% spray of Chlormequat Chloride (CCC), 0.1% spray of Tebuconazole and a combined spray of CCC + Tebuconazole in sub plots and replicated thrice. Growth regulators were used twice i.e. at first node and flag leaf stages.

Field preparation included one deep ploughing by mourld board plough followed by 2 cross harrowing and planking. The wheat variety HD-2967 was sown during second week of November with a recommended seed rate of 100 kg/ha. A 15 Mg/ha of FYM was applied 15 days before the sowing of crops as per treatment and well mixed in the soil. During both the seasons 1/3$^{rd}$ quantity of total N and whole amount of $P_2O_5$ and $K_2O$ were applied as basal at sowing, while remaining quantity of N were applied in two split of equal quantity, i.e. 1/3$^{rd}$ at first irrigation and 1/3$^{rd}$ at second irrigation. Crop was raised under irrigated condition and a total of six irrigations were applied at critical growth stages. Crop protection measures were followed as and when required. The growth and yield attributes were recorded as per the standard procedure by sampling from three places in each plot. The net plots, leaving the two border rows on the rows direction and half meter on opposite direction of the plots of wheat were harvested manually with sickle. The produce was kept for sun drying for some days in field and after drying, the biological yield was recorded and expressed in q/ha. After threshing the bundles from each plot, the grains were cleaned, dried and weighed. The grain yield was expressed in q/ha. Straw yield was obtained by subtracting the grain yield from the weight of total biological yield for individual plots and was expressed in tonnes/ha.

The net return of each treatment was calculated by deducting the total cost of cultivation from gross return of respective treatments and the benefit:cost ratio (B:C) was calculated by dividing the net return with total cost of cultivation. All data recorded were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez 1984) for split plot using SAS 9.3 (SAS Institute, Cary, NC). The least significant test was used to decipher the main and interaction effects of treatments at 5% level of significance ($P<0.05$).

## RESULTS AND DISCUSSION

*Effect of fertility levels and growth retardants on growth parameters and lodging of wheat*

The fertility practices had significant effect on plant height of wheat at all the growth stages (Table 1). At early growth stages (30 DAS), every successive increment in fertility level (control to 150% RDF) led significant difference in plant height and significantly maximum value of plant height (28.41 cm) was recorded with 150% RDFcompared to control (23.69 cm), 100% RDF (26.82 cm) and 150% RDF+FYM (27.46 cm). In contrast, at later stage (60, 90 DAS and at harvest) the crop fertilized with 150% RDF+FYM attainted significantly maximum plant height (59.94, 77.33 and 107.88 cm) over control (49.27, 64.85 and 91.68 cm), 100% RDF (56.29, 74.51 and 104.85 cm), respectively. However, the crop supplied with 150% RDF produced statistically similar plant height compared to 150% RDF+ FYM during these growth stages. The

Table 1 Effect of different nutrient management options and plant growth regulators on plant height and dry matter accumulation of wheat (pooled over 2 years)

| Treatment | Plant height (cm) | | | | Dry Matter accumulation (g $m^{-2}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | Harvest | 30 DAS | 60 DAS | 90 DAS | Harvest |
| *Fertility management practices* | | | | | | | | |
| Control | 23.69 | 49.27 | 64.85 | 91.68 | 26.83 | 148.44 | 702.05 | 1341.48 |
| 100% RDF | 26.82 | 56.29 | 74.51 | 104.85 | 31.74 | 274.34 | 805.90 | 1536.53 |
| 150% RDF | 28.41 | 57.75 | 75.99 | 107.51 | 34.31 | 285.51 | 834.66 | 1600.32 |
| 150% RDF+ FYM | 27.46 | 59.94 | 77.33 | 107.88 | 32.52 | 299.47 | 823.39 | 1553.02 |
| SEm ± | 0.18 | 0.41 | 0.98 | 1.57 | 0.63 | 6.13 | 10.49 | 23.27 |
| CD (P=0.05) | 0.45 | 0.99 | 2.39 | 3.85 | 1.53 | 15.00 | 25.66 | 56.93 |
| *Plant growth regulators* | | | | | | | | |
| Water spray | 26.54 | 57.01 | 76.00 | 106.75 | 31.04 | 245.16 | 799.56 | 1482.97 |
| CCC | 26.74 | 55.71 | 72.57 | 102.19 | 31.17 | 253.49 | 787.53 | 1503.06 |
| Tebuconazole | 26.95 | 56.05 | 73.14 | 103.53 | 31.57 | 250.54 | 790.61 | 1512.59 |
| CCC+ Tebuconazole | 26.14 | 54.48 | 70.98 | 99.45 | 31.61 | 258.58 | 788.30 | 1532.75 |
| SEm ± | 0.32 | 0.70 | 1.01 | 1.54 | 0.72 | 9.41 | 10.81 | 22.80 |
| CD (P=0.05) | 0.66 | 1.44 | 2.07 | 3.18 | 1.48 | 19.42 | 22.31 | 47.05 |

fertility levels also led significant effect on periodic dry matter accumulation of wheat (Table 1). At 30 DAS, crop fertilized using 150% RDF produced significantly highest mean dry matter (34.31 g/m) over control (26.83 g/m), 100% RDF (31.74 g/m). However, application of 150% RDF+FYM resulted in statistically similar dry matter accumulation compared to 150% RDF+ FYM at 30 DAS. In contrast, at later stage of growth (60, 90 DAS and at harvest) crop fertilized with 150% RDF+FYM recorded significantly highest dry matter accumulation over control and 100% RDF. However, the crop fertilized with 150% RDF produced statistically similar dry matter compared to 150% RDF+ FYM during these growth stages. The application of 150% RDF+FYM enhanced the dry matter of crop with the magnitude of 3.72 to 20.40% (30 DAS), 8.38 to 50.43% (60 DAS) 2.12 to 14.73% (90 DAS) and 1.01 to 13.71% (at harvest) over control and 100% RDF. Since, the major nutrients (nitrogen, phosphorus and potassium) 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. The results of study are in close agreement with the results of Fliessbach *et al.* 2007, Joergensen *et al.* 2010, Leifeld *et al.* 2009.

Table 2 Effect of different nutrient management options and plant growth regulators on wheat productivity potential (pooled over 2 years)

| Treatment | Grain yield (q/ha) | Straw yield (q/ha) | Biomass yield (q/ha) |
|---|---|---|---|
| *Nutrient management practices* | | | |
| Control | 27.44 | 33.82 | 61.26 |
| 100% RDF | 49.00 | 57.23 | 106.23 |
| 150% RDF | 53.86 | 64.81 | 118.68 |
| 150% RDF+ FYM | 55.85 | 68.08 | 123.92 |
| SEm ± | 1.10 | 1.54 | 2.23 |
| CD (P=0.05) | 2.70 | 3.78 | 5.45 |
| *Plant growth regulators* | | | |
| Water spray | 44.04 | 54.97 | 99.01 |
| CCC | 47.17 | 56.23 | 103.40 |
| Tebuconazole | 46.35 | 55.73 | 102.08 |
| CCC+ Tebuconazole | 48.59 | 57.01 | 105.60 |
| SEm ± | 1.72 | 1.96 | 3.56 |
| CD (P=0.05) | 3.55 | 4.04 | 7.36 |

At early growth stages of wheat (30 DAS), all the tested growth retardants were remained statistically at par for plant height. However, at later stage (60, 90 DAS and at harvest), the combined application of CCC+Tebuconazole resulted in significantly lowest plant height compared to water spray and other growth retardants. The combined application of CCC +Tebuconazole reduced the plant height of wheat with the magnitude of 4.62, 2.25 and 2.86% at 60 DAS, 7.07, 2.24 and 3.05% at 90 DAS and 7.35, 2.76 and 4.11% at harvest over water, CCC and Tebuconazole , respectively. However, all the growth retardant found statistically at par for dry matter accumulation. Though, slight reduction in dry matter was observed with the application of growth retardants over water spray at later stage of the wheat. Plant height and strength of basal internodes are closely related to lodging resistance (Knapp *et al.* 1987, Berry *et al.* 2000, Zhang *et al.* 2010, Wei *et al.* 2008). Based on the results, it is suggested that, the combined application of CCC+Tebuconazole can avoid risk of lodging occurred by

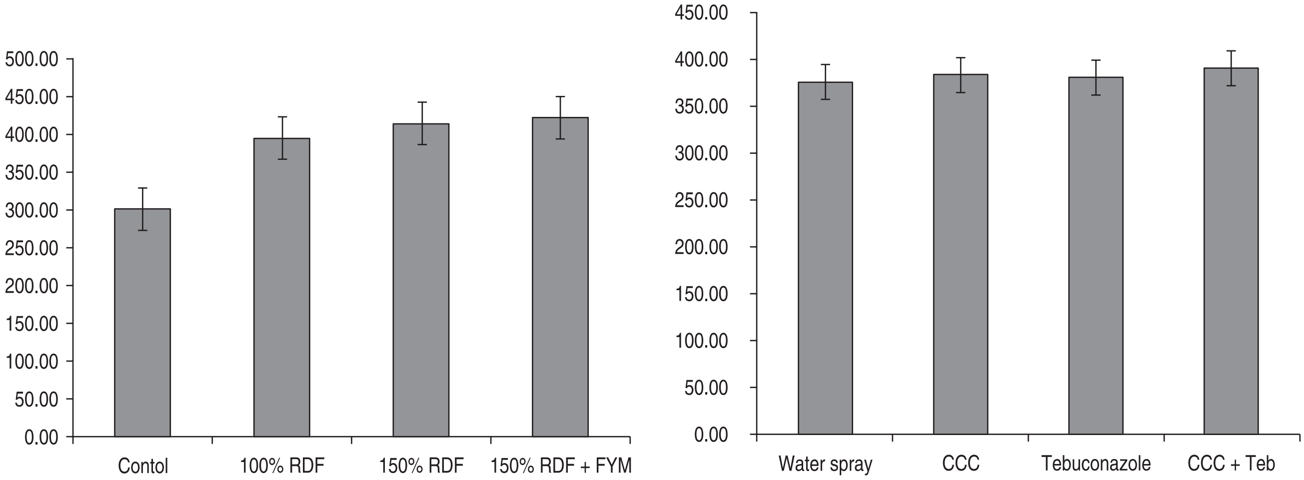


Fig 1 Effect of different nutrient management options plant growth regulators and growth retardants on spike length, test might and Effective tillers ($m^{-2}$) of wheat.

altering the plant height. The results of study are valuable for enhancing lodging resistance by reducing plant height of wheat to prevent lodging and improving grain yield and quality.

*Effect of fertility levels and growth retardants on yield attributes of wheat*

The analysis of variance data indicated that nutrient management practices had significant effect on yield attributes of wheat (number of effective tillers, spike length and test weight) of wheat (Fig 1 and 2). The significantly maximum number of effective tillers (423.42/$m^2$), spike length (10.66 cm) and test weight (40.32 g) were registered with 150% RDF+FYM. Whereas, minimum number of effective tillers (330.25/$m^2$), spike length (7.10 cm) and test weight (32.96 g) were recorded under control. However, crop supplied with the 100% RDF and 150% RDF recorded statistically similar results for aforesaid yield attributes compared with 150 RDF+FYM. The combined application of 150% RDF along with FYM enhanced the number of effective tillers by 22.00, 6.16 and 1.71%, spike length by 33.40, 12.28 and 3.55% and test weight by 18.26, 3.21 and 1.36% over control, 100% RDF and 150% RDF, respectively. The optimal and balanced supply of nutrient (macro and micronutrient) from inorganic and organic fertilizers led to higher growth and development of plants and side by side improve the physical, chemical, biological and hydrological properties of soil which further provide an optimum environment for higher growth and development of plants reflected by higher yield attributes of plants (Behera *et al.* 2007, Mavi and Benbi 2008).The number of effective tillers and spike length under different growth retardant were found statistically at par, although highest values were recorded with combined use of CCC +Tebuconazole (Fig 1 and 2). However, the growth regulators led significant effect on test weight and the maximum values were recorded with the combined application of CCC +Tebuconazole. The magnitude of increase in test weight with the combined spray of CCC and Tebuconazole over water spray, CCC + Tebuconazole was 7.71, 2.63 and 2.84%, respectively. Similar results on wheat with the use of plant growth retardants were also reported by Guoping *et al.* (2001) and Rajala *et al.* (2002).

*Effect of fertility levels and growth retardants on crop productivity*

Present findings revealed that fertility levels had significant effect on wheat productivity (Table 2).The mean

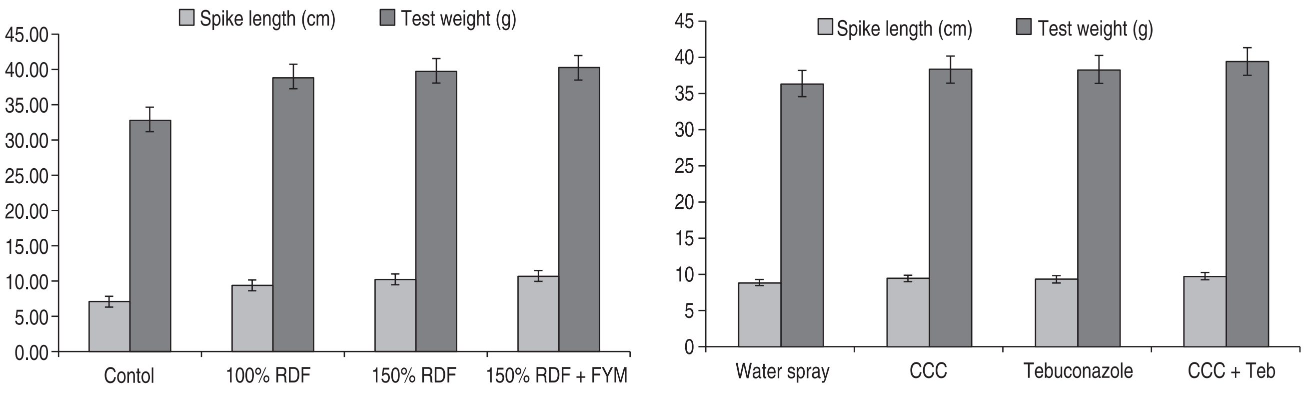


Fig 2 Effect of different nutrient management options, plant growth regulators and growth retardents on spike length and test weight of wheat.

maximum grain and straw yield of wheat were recorded with 150% RDF+ FYM which were 50.87 and 12.26% and 50.31 and 15.92% higher compared to control and 100% RDF, respectively. However, the wheat crop fertilized using 150% RDF was found statistically at par with 150% RDF+ FYM. Similarly the mean total biomass (grain+straw) was also found maximum with application 150% RDF+ FYM. It enhanced the biomass yield of wheat by 50.56 and 14.27 % compared to control and 100% RDF, respectively. Similar to grain and straw yield, the crop fertilized using 150% RDF yielded statistically similar biomass compared to 150% RDF+ FYM. This increment in crop productivity might be result of higher plant growth, dry matter accumulation and yield attributes with the combined application of organic and inorganic compared to when chemical fertilizer applied alone. Similar results were also reported by many other researchers which state that integration of chemical and organic sources led to higher crop productivity (Manna *et al.* 2003 and Ram *et al.* 2015). Moreover, the use of organics with inorganic fertilizers attributed to the better utilization of soil moisture, nutrients uptake and less fluctuation in the soil temperature (Halvorson *et al.* 2002) and improve soil organic matter which increase the soil water holding capacity, soil aggregation, microbial activity and soil porosity which ultimately led to higher crop productivity (Zamir *et al.* 2010).

Wheat yield (grain, straw and biomass) due to different growth retardant treatments were found statistically at par, although highest values of were recorded with combined use of CCC and Tebuconazole over others treatments. The magnitude of increase in mean grain, straw yield and biological yield with the combined spray of CCC and Tebuconazole over water spray were 9.37, 3.57 and 6.24%, respectively. These results are in close agreement with the results of earlier researchers (Tripathi *et al.* 2003, Webster and Jackson 1993) who stated that growth inhibitor significantly reduced plant height and simultaneously produced equal biomass over no application.

*Effect of fertility levels and growth retardants on farm profitability*

The highest cost of cultivation of wheat was recorded under the treatment fertilized through 150% RDF+ FYM and with combined application of CCC and Tebuconazole over others treatments (Table 3). Significantly highest mean gross returns (₹ 117982) and net returns (₹ 80697) were observed with application of 150% RDF+ FYM compared to control (₹ 58111 and ₹ 31823) and 100% RDF (₹ 102516 and ₹ 70231), respectively. However, the wheat crop fertilized with 150% RDF was found statistically at par with 150% RDF+ FYM. The application of 150% RDF+ FYM increased the mean gross return by 50.74, 13.10 and 3.83% and mean net returns by 60.56, 12.96 and 3.13% over control, 100% RDF and 150% RDF respectively. However, the maximum B:C ratio (2.22) was reported with application of 150% RDF compared to control (1.21), 100% RDF (2.18) and 150% RDF+FYM (2.16). Among the growth retardant treatments, the highest cost of cultivation (₹ 33748), gross returns (₹ 101764), net returns (₹ 68016) and B:C ratio (1.98) were recorded with combined application of use of CCC and Tebuconazole. Whereas minimum values for cost of cultivation (₹ 31398), gross returns (₹ 93552), net returns (₹ 62154) and B:C ratio (1.92) were recorded with water spray (control). The combined application of CCC and Tebuconazole increased gross and net returns with magnitude of 8.07, 2.58 and 4.09% and 8.62, 2.76 and 5.01% over water spray and when CCC and tebuconazole used alone, respectively. Thus, the combined application of CCC and Tebuconazole provided additional net retuns of ₹ 5862 to the farmers over water spray (control). The higher crop productivity of crop might be the principal reasons for higher net returns under integrated nutrient management and combined application of CCC and Tebuconazole. Similar results of higher farm profitability were also reported by Benbi *et al.* (2012), Bhandari *et al.* (2002) for integrated nutrient management and Guoping *et al.* (2001) for plant growth regulators.

Table 3 Effect of different nutrient management options and plant growth regulators on farm profitability (pooled over 2 years)

| Treatments | Cost of cultivation (₹/ha) | Gross return (₹/ha) | Net return (₹/ha) | B:C ratio |
|---|---|---|---|---|
| *Nutrient management practices* | | | | |
| Control | 26287 | 58111 | 31823 | 1.21 |
| 100% RDF | 32285 | 102516 | 70231 | 2.18 |
| 150% RDF | 35284 | 113452 | 78167 | 2.22 |
| 150% RDF+ FYM | 37284 | 117982 | 80697 | 2.16 |
| *Plant growth regulators* | | | | |
| Water spray | 31398 | 93552 | 62154 | 1.92 |
| CCC | 32998 | 99137 | 66139 | 1.96 |
| Tebuconazole | 32998 | 97606 | 64608 | 1.91 |
| CCC+ Tebuconazole | 33748 | 101764 | 68016 | 1.98 |

*Conclusion*

The results of this study demonstrated that cultivation of wheat with the combined use CCC and Tebuconazole and 150% RDF+ FYM resulted in significant improvement in the growth, productivity and profitability. Therefore, it can be concluded that integrated nutrient management using 150% RDF+ FYM and combined application of CCC and Tebuconazole plant growth regulators can be advocated as sustainable strategy for enhancing productivity and profitability of wheat cultivation in semi-arid conditions.

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