

Enhancement of Yield Attributes and Seed Yield in Wheat through Source-Sink Manipulation under Different Moisture Regimes

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ABSTRACT: Field experiments were conducted during *rabi* season in three consecutive years (2012-13, 2013-14 and 2014-15) with two wheat varieties (HI- 1563 and Raj-3765) to determine the effect of GA₃ spraying on source-sink relations in wheat crop under normal and moisture deficit conditions. It was observed that spraying of GA₃ at the time of anthesis significantly increased the number of seed/spike, biological yield, 1000 seed weight, grain yield and finally seed yield over control. The influence of GA₃ @ 100 ppm was higher compared to GA₃ @ 50 ppm and control. Yield attributes *viz*: seed number, 1000 seed weight, grain yield and finally seed yield and its recovery percentage were higher under normal moisture condition than the water deficit condition. Variety HI 1563 displayed the higher means values over Raj-3765 for almost all the characters.

Keywords: Gibberellins, Moisture stress Source, Sink, Wheat

Plant growth regulators (PGRs) including auxin, gibberellins (GAs), cytokinins and abscisic acid (ABA) have prominent role in regulation of source-sink relationship at structural, function and molecular level [1-3]. Among these PGRs, gibberellins are very specific, as it enhances source and sink potential through increasing photosynthetic enzyme activities, increasing leaf area for higher interception of photosynthetically active radiation and enhancing nutrient use efficiency [4]. In addition, GAs is known to activate sucrose phosphate synthetase (SPS) for sucrose formation and loading into the phloem, which is being unloaded into the sink through invertase enzyme. Exogenous application of GA₃ using certain concentration has shown beneficial effects for various crops under abiotic and biotic stresses, since it may provide a mechanism to regulate the metabolic process as a function of sugar signaling and anti-oxidative enzymes. Thus, adequate quantity of exogenous GAs application at an appropriate time would regulate crop source-sink relation to get maximum yield under both optimum and limiting environmental conditions. Wheat (*Triticum aestivum*) is the most important cereal crop of the world and about two third of the world population lives on wheat grain [5]. The physiological basis of dry matter production

depends on the source-sink relationship, where photosynthesis is the source for potential capacity, while sink is to store the food material. When any one of these two is limited higher yield in wheat crops cannot be expected [6]. Literatures [7] reviewed on the magnitude of the mean grain weight response as a function of the assimilate availability during grain filling period to test quantitatively, whether source or sink limitation in wheat grain growth period was predominant. They concluded that under most conditions grain growth in wheat was apparently more sink, than source-limited. Keeping the above views in mind the present research work was formulated to understand the role of gibberellins in regulation of source-sink relation under optimal and limiting environmental condition and also to see the influence of source-sink manipulation on grain yield and finally seed yield in wheat.

MATERIALS AND METHODS

Field experiments were conducted at the research farm of ICAR-Indian Institute of Seed Science, Mau during *rabi* season in three consecutive years (2012-13, 2013-14 and 2014-15) with two wheat varieties (HI-1563 and Raj-3765) to see the effect of Spraying of GA₃ on source –

sink relations in wheat crop under normal and moisture deficit conditions. Healthy seeds of wheat varieties viz: HI-1563 and Raj-3765 were taken from breeding section of the institute and sown in respective plots on recommended spacing in three replications under strip plot design with 6x4 meter plot size during second week of December each year. Moisture level was maintained in main plot, whereas varieties and spraying doses were done in sub-plots. Recommended doses of NPK (120:60:40kg/ha), half dose of nitrogen and full dose of phosphorus and potash have been applied as basal dose and remaining half dose of nitrogen as top dressing in two equal split doses at tillering and booting stages, respectively. Under normal moisture conditions, five irrigations (I_1) were applied and to maintain moisture deficit conditions only two irrigations (I_2) were given. GA₃ solutions of 50 and 100ppm were prepared freshly in the laboratory and sprayed in respective plots at the anthesis stage of crop (around 50 days after sowing) using knap-sack sprayer, with a quantity of 1000 ml sprayed solution /plot. Observations on seed quality parameters such as germination, speed of germination, seedling length and dry weight, vigor index I & II were recorded at early stages and number of tillers was counted after 45 days of sowing as per the method suggested [8]. Irrigations in respective plots were scheduled as per recommendation for wheat crop. Plant height and yield attributes including spike length, number of grains/spike, 1000 seed weight, biological and grain yield were recorded at harvest.

Statistical Analysis

Data recorded were tabulated and statistically analyzed following the standard statistical tools. The grain yield obtained plot wise was processed in mini seed processing plant for seed yield and to compute the recovery %.

RESULTS AND DISCUSSION

Exogenous application of GA₃ with 50 and 100 ppm concentration was carried out at anthesis stage of standing wheat crop hence no any effect was observed on seed quality parameters. The response of GA₃ spraying on plant height showed improvement in both the varieties under normal as well as water stress condition. In doses of GA₃ (50 and 100ppm) applied, GA₃@100ppm was more effective than GA₃ @50ppm and showed significant improvement in plant height over control under drought conditions. Gibberellins, particularly GA₃, is the potential plant growth regulator responsible for cell elongation and enlargement which might be the reason for increased plant height under both the moisture levels but the effectiveness was significantly higher in drought condition since the GA₃ plays a protective role in limiting environmental conditions (Table 1).

Yield attributes

Spraying of GA₃@ 100ppm significantly improved the number of seeds/spike over control in both the varieties evaluated under normal as well as stress condition (Table 2). Varieties did not vary for number of seeds /spike and

Table 1. Effect of GA₃ spraying on Plant height (cm) in wheat

| Treatment/variety | Moisture level | | | | | |
|---|----------------|-------|-------|-------|-------|-------|
| | I_1 | | | I_2 | | |
| | V_1 | V_2 | Mean | V_1 | V_2 | Mean |
| T ₁ Control | 84.27 | 83.06 | 83.67 | 80.67 | 78.52 | 79.29 |
| T ₂ Spraying of GA ₃ @50 ppm | 85.07 | 84.52 | 84.79 | 82.50 | 81.55 | 82.03 |
| T ₃ Spraying of GA ₃ @100 ppm | 86.69 | 85.29 | 85.99 | 86.84 | 84.56 | 85.7 |
| Mean | 85.35 | 84.29 | | 83.14 | 81.55 | |
| | | SE± | | CD | | |
| Treatment (T) | | 1.78 | | 4.95 | | |
| Variety (V) | | 0.32 | | 1.39 | | |
| V × T | | 1.79 | | 4.97 | | |
| Irrigation (I) | | 1.62 | | 3.53 | | |
| T × I | | 2.81 | | 6.12 | | |
| V × I | | 2.29 | | 4.99 | | |
| T × V × I | | 3.97 | | 8.65 | | |

Table 2. Effect of GA3 spraying on No. of seeds/spike

| Treatment/variety | Moisture level | | | | | |
|---|----------------|----------------|-------|----------------|----------------|-------|
| | I ₁ | | | I ₂ | | |
| | V ₁ | V ₂ | Mean | V ₁ | V ₂ | Mean |
| T ₁ Control | 37.46 | 37.2 | 37.33 | 36.9 | 35.9 | 36.4 |
| T ₂ Spraying of GA ₃ @50 ppm | 39.63 | 38.08 | 38.83 | 37.3 | 37.1 | 37.2 |
| T ₃ Spraying of GA ₃ @100 ppm | 40.5 | 40.0 | 40.25 | 39.8 | 37.7 | 38.75 |
| Mean | 39.19 | 38.41 | | 39.0 | 36.9 | |
| | SE± | | | CD | | |
| Treatment (T) | 0.74 | | | 2.06 | | |
| Variety (V) | 2.04 | | | 8.79 | | |
| V × T | 2.19 | | | 6.11 | | |
| Irrigation (I) | 1.42 | | | 3.10 | | |
| T × I | 2.46 | | | 5.36 | | |
| V × I | 2.01 | | | 4.38 | | |
| T × V × I | 3.48 | | | 7.58 | | |

Table 3. Effect of GA3 spraying on 1000 Seed weight (g)

| Treatment/variety | Moisture level | | | | | |
|---|----------------|----------------|-------|----------------|----------------|-------|
| | I ₁ | | | I ₂ | | |
| | V ₁ | V ₂ | Mean | V ₁ | V ₂ | Mean |
| T ₁ Control | 35.84 | 34.81 | 35.32 | 33.38 | 31.12 | 32.25 |
| T ₂ Spraying of GA ₃ @50 ppm | 37.14 | 36.61 | 36.87 | 36.93 | 36.5 | 36.71 |
| T ₃ Spraying of GA ₃ @100 ppm | 43.05 | 37.92 | 40.48 | 40.82 | 37.85 | 39.34 |
| Mean | 38.68 | 36.44 | | 37.04 | 35.15 | |
| | SE± | | | CD | | |
| Treatment (T) | 0.95 | | | 2.64 | | |
| Variety (V) | 0.76 | | | 3.29 | | |
| V × T | 0.89 | | | 2.48 | | |
| Irrigation (I) | 0.94 | | | 2.06 | | |
| T × I | 1.63 | | | 3.56 | | |
| V × I | 1.33 | | | 2.91 | | |
| T × V × I | 2.31 | | | 5.04 | | |

also there was no significant effect of moisture level on this character. The interactions of VxT, VxI, TxI and VxTxI were also insignificant. Higher seed number was recorded in Raj-3765 over HI-1563 irrespective of treatments and moisture levels. The improvement in seed number/spike through GA₃ @100ppm spraying was 7.8 and 6.40 % over control under normal and stress condition, respectively. Thousand (1000) seed weight (test weight) showed significant enhancement through GA₃@100 ppm spraying over control (Table 3). The improvement recorded with GA₃ @50 ppm spray was not significantly higher when compared with control. No significant difference was noted between varieties evaluated at both

the moisture level though relatively higher seed weight was recorded under normal irrigation condition (I₁). Improvement in average test weight (1000 seed weight) was 14.61% under normal irrigation and 21.98% under deficient (stress) condition over control indicating thereby the positive effects of GA₃@100ppm spraying (Figure 1). Biological yield recorded at harvest presented in (Table 4) revealed that there was significant increase with the spraying of GA₃ @100ppm at the time of anthesis in both the varieties evaluated over control. Biological yield was slightly improved with the spraying of GA₃ @50 ppm and statistically it was not significant over control. The differences between varieties were insignificant

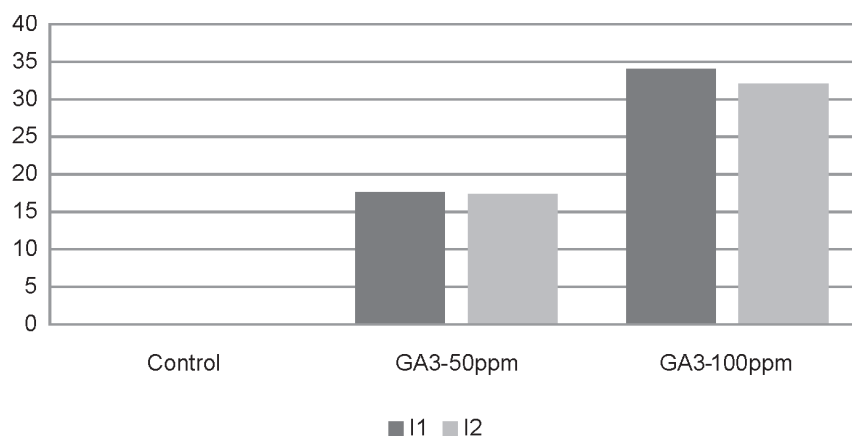


Figure 1. %increase in 1000 Grain weight

Table 4. Effect of GA3 spraying on Biological Yield (kg/plot)

| Treatment/variety | Moisture level | | | | | |
|---|----------------|----------------|-------|----------------|----------------|-------|
| | I ₁ | | | I ₂ | | |
| | V ₁ | V ₂ | Mean | V ₁ | V ₂ | Mean |
| T ₁ Control | 16.06 | 15.6 | 15.83 | 14.86 | 14.13 | 14.49 |
| T ₂ Spraying of GA ₃ @50 ppm | 16.96 | 16.83 | 16.89 | 16.66 | 15.03 | 15.84 |
| T ₃ Spraying of GA ₃ @100 ppm | 18.63 | 17.7 | 18.16 | 18.6 | 16.93 | 17.76 |
| Mean | 17.21 | 16.71 | | 16.70 | 15.80 | |
| | SE± | | | CD | | |
| Treatment (T) | 1.03 | | | 2.26 | | |
| Variety (V) | 0.71 | | | 1.55 | | |
| V × T | 1.14 | | | 2.48 | | |
| Irrigation (I) | 0.77 | | | 1.68 | | |
| T × I | 1.33 | | | 2.91 | | |
| V × I | 1.09 | | | 2.38 | | |
| T × V × I | 1.89 | | | 4.11 | | |

irrespective of treatments and the moisture level. Highest biological yield was harvested in Raj-3765 under normal as well stress condition with the spraying of GA₃@100ppm. Overall, the biological yield harvested was higher in normal irrigation as compared to moisture deficit conditions. Interactions of treatments, varieties and irrigation were not significant. Enhancement in biological yield was 14.71% in normal irrigation and 22.56% in deficient irrigation over control which indicates relatively more response of GA₃ spraying under stress condition. Spraying of GA₃@100ppm in standing wheat crop significantly improved the grain yield in both the varieties evaluated over untreated control (Table 5). Increase in grain yield with the spray of GA₃@50 ppm was higher than control but statistically insignificant. Varieties did not vary significantly in grain yield irrespective of treatment

and moisture levels, though relatively higher yield was recorded in Raj-3765. Interaction of VxT was significant and highest grain yields were recorded with GA₃@100pp in Raj-3765 under both moisture levels. Percent of increase over control in grain yield was 34.02 and 32.05 under normal and stress conditions, respectively (Figure 2). After seed processing the seed yield obtained is given in (Table 6) indicated that with the spraying of GA₃@50 and 100ppm, there was enhancement in seed yield and seed recovery % over untreated control. The average increase through spraying of GA₃ 50 ppm was more than 5% over control under normal condition but under moisture deficit condition it was negligible indicating thereby no response of GA₃@50 ppm under moisture deficit. Whereas application of GA₃@100ppm was quite effective and showed more than 9 and 10% increase in

Table 5. Effect of GA3 spraying on Grain Yield (kg/plot)

| Treatment/variety | Moisture level | | | | | |
|---|----------------|----------------|------|----------------|----------------|------|
| | I ₁ | | | I ₂ | | |
| | V ₁ | V ₂ | Mean | V ₁ | V ₂ | Mean |
| T ₁ Control | 5.01 | 4.7 | 4.85 | 4.98 | 4.38 | 4.68 |
| T ₂ Spraying of GA ₃ @50 ppm | 5.83 | 5.58 | 5.70 | 5.28 | 5.03 | 5.49 |
| T ₃ Spraying of GA ₃ @100 ppm | 6.88 | 6.13 | 6.50 | 6.62 | 5.75 | 6.18 |
| Mean | 5.91 | 5.47 | | 5.63 | 5.05 | |
| | SE± | | | CD | | |
| Treatment (T) | 0.76 | | | 1.66 | | |
| Variety (V) | 0.29 | | | 0.64 | | |
| V × T | 0.31 | | | 0.86 | | |
| Irrigation (I) | 0.41 | | | 0.90 | | |
| T × I | 0.72 | | | 1.56 | | |
| V × I | 0.58 | | | 1.27 | | |
| T × V × I | 1.01 | | | 2.21 | | |

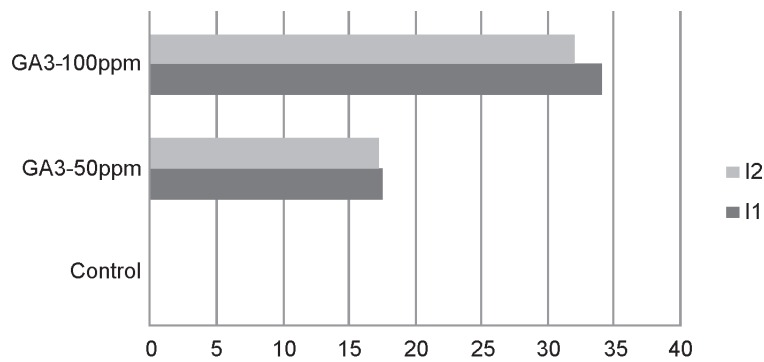


Figure 2. %increase in Grain yield(kg)

Table 6. Effect of GA3 spraying on Seed Yield (Kg/Plot) and Seed Recovery %

| Treatment/variety | Moisture level | | | | | |
|---|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | I ₁ | | | I ₂ | | |
| | V ₁ | V ₂ | Mean | V ₁ | V ₂ | Mean |
| T ₁ Control | 3.80 (75.84) | 3.48 (74.04) | 3.64 (75.05) | 3.63 (72.90) | 3.15 (71.91) | 3.39 (72.43) |
| T ₂ Spraying of GA ₃ @50 ppm | 4.72 (80.96) | 4.46 (79.92) | 4.60 (80.71) | 4.11 (77.84) | 3.87 (76.94) | 4.00 (72.86) |
| T ₃ Spraying of GA ₃ @100 ppm | 5.85 (85.03) | 5.15 (84.01) | 5.50 (84.61) | 5.48 (82.78) | 4.74 (82.43) | 5.11 (82.68) |
| Mean | 4.79 (81.05) | 4.36 (79.70) | | 4.40 (78.15) | 3.92 (77.62) | |

Values given in brackets are the seed recovery %

seed yield under normal and water deficit conditions, respectively over control.

The above results indicate that spraying of GA₃@100ppm during anthesis showed 9-10% seed yield enhancement

with an incurred cost of Rs.1000/ha. In varieties, the recovery % was almost at par but HI-1563 was relatively superior under both the conditions evaluated. Among the yield attributes, number of seeds/spike, 1000 seed weight,

biological yield, grain yield and finally seed yield and its recovery percent were significantly enhanced over untreated control by spraying of GA₃@100ppm at anthesis stage in standing wheat crop. The improvement in above mentioned yield contributing characters is due to the prominent role of gibberellins in the regulation of source-sink relationship in plants at structural, functional and molecular level [1-3]. The enhancement of sink in the form of increased seed number /spike, 1000 seed weight, biological yield, grain yield and seed recovery percent are the results of increased source for higher interception of photo synthetically active radiation, increased photosynthetic enzymes and nutrient use efficiency, which might play specific role of gibberellins applied exogenously to the wheat crop [4].

CONCLUSION

Exogenous application of an adequate quantity of GA₃ (100ppm) at anthesis time regulated plant source-sink potential to get maximum yield under both optimum and limiting environmental conditions. Spraying dose of gibberellic acid at anthesis stage has been standardized and optimized in wheat crop, which enhanced the dry matter production and there by improved the source-sink relationship. The sources have potential for photosynthesis and sink store food material. Balancing growth in source and sink organs had certainly ensured the efficient assimilate availability during grain filling period and as a result the grain yield followed by seed

yield was improved under both normal and limited environmental conditions.

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