*Pak. J. Bot.*, 51(2): 451-459, 2019. DOI: 10.30848/PJB2019-2(11)

# EFFECT OF NAPHTHALENEACETIC ACID ON ROOT AND PLANT GROWTH AND YIELD OF TEN IRRIGATED WHEAT GENOTYPES

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**Abstract**

Plant growth regulators (PGRs), such as 1-naphthaleneacetic acid (NAA), gibberellins, cytokinins, abscisic acid, and ethylene have become commercialized in some countries to increase the productivity of field crops and to fortify the value of horticultural crops. However, very limited research has been conducted in Bangladesh on root growth, plant biomass and yield of wheat (*Triticum aestivum* L.) using NAA. In this context, an experiment was conducted over two consecutive seasons, from November to April, in the research field of the Wheat Research Center (WRC) (under Old Himalayan Piedmont Plain), Dinajpur-Bangladesh. Treatments consisted of the application of 25 mg/l NAA in five temporal regimes: 1) NAA applied at 20, 35 and 50 days after emergence (DAS); 2) NAA applied at 20 and 35 DAS; 3) NAA applied at 20 and 50 DAS; 4) NAA applied at 35 and 50 DAS; 5) a control (without NAA). Treatments were applied to 10 irrigated spring wheat genotypes i.e., 'Kanchan', 'Protiva', 'Surov', 'Gourov', 'BAW 944', 'BAW 953', 'BAW 994', 'Akbar', 'Agrhani' and 'Sonalika', and arranged in a split-plot design, namely as five NAA treatments as the main plots and 10 wheat genotypes as the sub-plots. In both seasons, data on root fresh and dry weight, root length, total plant dry biomass (TDM), grain yield (GY) and yield attributes of wheat were significantly ($p \leq 0.05$) influenced by the NAA application regime and genotype. However, maximum root fresh and dry weight and longest roots were recorded in treatment 2 for 'Gourav'. Maximum TDM was recorded at 40 and 50 DAS for 'BAW 944' in treatment 3. Significantly similar and maximum TDM at 60 DAS was found for 'Kanchan' and 'Sourav' in treatment 1 and at 70 DAS for 'Sourav' in treatment 2. 'BAW 994', 'BAW 953' and 'Agrahani' produced significantly similar and maximum number of spikelets spike$^{-1}$ in treatment 2. 'BAW 944' and 'BAW 953' showed significantly similar 1000-grain weight in treatment 3 while smallest grain size was obtained in 'BAW 953' in the control treatment. 'BAW 953' produced highest GY in treatment 1, and was statistically similar to 'BAW 994' and 'Protiva' after the application of treatments 2 and 4. Therefore, the application of NAA at 20, 35 and 50 DAS in all genotypes was more effective (i.e., better root growth and yield) than the control plot. Among the 10 tested genotypes, 'BAW 953' and 'BAW 994' responded most to NAA.

**Key words:** Naphthalene acetic acid, Wheat, Growth, Yield and yield attributes.

## Introduction

Globally, wheat (*Triticum aestivum* L.) is the most widely grown food cereal crop (FAO & WFP, 2015). However, the International Food Policy Research Institute projected (IFPRI) that world demand for wheat would rise from 552 million tons in 1993 to 775 million tons by 2020, and by a total of 60% by 2050, due to rise in global population (Singh *et al.*, 2016). In Bangladesh, after rice, wheat is the second most important cereal and contributes about 7% of the total demand of cereals as food (Hossain & Teixeira da Silva, 2013; Timsina *et al*., 2018), and occupies about 4% of the total area under cultivated and 11% of the area in the Rabi season (BBS, 2016). In 2015-16, 1.36 million tons of wheat was harvested from 0.49 million ha of land, according to the BBS (2016). The current demand of wheat in Bangladesh is 5.9 million tons with demand increasing by 10% per year (BBS, 2016). Therefore, to meet the demand of wheat for an increasing population, greater efforts are needed to develop new wheat varieties with higher grain yield (GY) potential and to develop and adopt improved crop management practices (Timsina *et al.*, 1998, 2010).

There is little scope to increase agricultural lands suitable for cultivation (Reynolds *et al*., 2009; Long & Ort, 2010; Li *et al*., 2016). Therefore, to meet future food demand of increasing populations, an intensive agricultural system is the best way by using a small piece of land to establish a low fallow ratio, higher use of inputs and higher productivity per unit area (Tilman *et al.*, 2002; Henkel, 2015). Most commercial agricultural systems are intensive, with multiple crops cultivated per year, reducing the frequency of fallow years, and including high-yielding crop cultivars to raise GY (Tilman *et al.*, 2002). Such systems also involve an increased use of balanced fertilizers, plant growth regulators (PGRs), pesticides, mechanized agriculture as well as favourable growing conditions, i.e., optimized weather, soil, and water conditions, and fewer weeds and reduced pest infestation (Henkel, 2015).

PGRs have been used to increase the GY of major cereal crops, including wheat, and have already become commercialized in the EU, USA and Japan (Bakhsh *et al.*, 2011a; Adam & Jahan, 2011; Basuchaudhuri, 2016). Although PGRs have long been used in agriculture for crop cultivation, their application is limited and mainly used in commercial agricultural systems to improve the quality and quantity of high-value field and horticultural crops (Pandey *et al.*, 2001; Fatima *et al.*, 2008). Among PGRs, 1-naphthaleneacetic acid (NAA) is a synthetic auxins that plays a key role in RNA synthesis, membrane permeability and water uptake, and is also involved in many physiological processes such as root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting and flowering, cell elongation, cell division, and vascular tissue development (Alabadí *et al.,* 2009; Basuchaudhuri, 2016). Bakhsh *et al*., (2011a), Adam & Jahan (2011) and Basuchaudhuri (2016) documented that the exogenous application of naturally occurring or synthetic PGRs affect the endogenous hormonal pattern of a plant either by supplementation of sub-optimal levels or by interaction with their synthesis, translocation or inactivation of existing hormone levels. An appropriate concentration of NAA affects the growth and yield of a number of plants as reported by earlier studies around the world. However, in Bangladesh, very limited research has been conducted on root growth, plant biomass and yield of wheat genotypes by the exogenous application of NAA. In this context, the present study was undertaken to evaluate the impact of NAA on root growth, plant biomass and yield of 10 irrigated spring wheat genotypes.

## Materials and Methods

**Location of the experiment:** The experiment was conducted in a research field of the Wheat Research Center (WRC), BARI, Nashipur, Dinajpur (under the Agro Ecological Zone Old Himalayan Piedmont Plain) over two consecutive years during the wheat season (November to April). The geographical position of the area is between N 25º 44.574" and E 88º 40.344”, and 40 m above sea level.

**Experimental design and treatments:** Treatments were five application times of NAA at 25 mg/l: 1. NAA applied at 20, 35 and 50 days after sowing (DAS), 2. NAA applied at 20 and 35 DAS, 3. NAA applied at 20 and 50 DAS, 4. NAA applied at 35 and 50 DAS, and a control (without NAA), and 10 irrigated spring wheat genotypes (‘Kanchan’, ‘Protiva’, ‘Surov’, ‘Gourov’, ‘BAW 944’, ‘BAW 953’, ‘BAW 994’, ‘Akbar’, ‘Agrhani’ and ‘Sonalika’) arranged in a split-plot design (i.e., five spray application times of NAA were selected as the main plots and the 10 wheat genotypes as the sub-plots). According to these treatments (application at different DAS), 30 ml of NAA per 10 liter of water was applied with a Knapsack sprayer as a foliar spray. The unit plot size (6×3 m) consisted of 30 rows, each 3 m long, and a row-to-row distance of 20 cm and a block-to-block distance of 1.0 m.

**Variety, seeding rate, sowing time, seed treatment and fungicide:** The 10 wheat genotypes were collected from the WRC, BARI, Nashipur, Dinajpur. In both seasons, all genotypes were sown in lines by hand on November 20. Seeding rate was 120 kg $ha^{-1}$ treatment. Before sowing, seeds of all genotypes were treated with a fungicide, Vitavax-200 (37.5% Carboxin + 37.5% Thiram) (marketed by Hossain Enterprise CC Bangladesh Ltd.).

**Land preparation, fertilizer, irrigation, mulching and weeding:** Land was thoroughly prepared and leveled by ploughing and laddering. Weeds and stubble were removed from the field at the time of final land preparation. Fertilizer (N, P, K, S and B) was added at 100, 27, 40, 20, 1 kg $ha^{-1}$, respectively, as recommended by the WRC-BARI. Before sowing seeds, and during final land preparation, two-thirds of N and a full amount of the other fertilizers were applied as basal (Akhter *et al.*, 2016). The remaining N fertilizer was provided after the first irrigation (20 DAS) while second and third irrigations were added at 52 and 73 DAS.

**Data collection and analysis:** Root growth per cubic centimeter of soil was studied at 90 DAS, at the early grain-filling stage. Roots with soil were collected from randomly selected hills of each treatment and also from between the two lines of adjacent hills by vertically penetrating a core sampler to a depth of 0-10 cm. Root samples were watered individual in a polyethylene bag and kept for 12 h to allow the soil to swell and loosen. Samples were then washed in pond water using a cloth net over a plastic net tray. Root fresh weight (RFW; mg cc $soil^{-1}$) was assessed immediately. To measure root dry weight (RDW; mg cc $soil^{-1}$), samples were dried in an oven at 70°C for 72 h. Root length (RL; cm cc $soil^{-1}$) was measured manually using calibrated paper.

Total biomass dry weight (TDM; g $m^{-2}$) at different DAS was recorded from each treatment, starting from 40 DAS with a 10-day interval up until 100 DAS. TDM was assessed immediately after sampling each treatment. To determine TDM, samples were dried in an oven at 70°C for 72 h, and weighed on an electronic balance to two decimal places.

The crop was harvested on April 4 in the first year, and on April 3 in the second year. GY, biomass yield (BY) at harvest, and yield-related attributes were recorded from a 2 × 2 m (2 m long; 10 rows) area from the center of each plot. Samples from each plot were bundled separately, tagged and threshed manually on a threshing floor. Bundles were thoroughly dried in bright sunshine before their weights were recorded. Data on plant height (cm), spikes $m^{-2}$, spikelets $spike^{-1}$, 1000-grain weight (g; TGW), and GY (kg $ha^{-1}$) were recorded. GY and TGW were recorded at 12% moisture content.

Data analysis: Data were statistically analyzed using MSTAT-C statistical package of Michigan State University, USA (Russell, 1986). Mean separation test was done by Duncan’s new multiple range test (DNMRT) at a 5% probability level (Steel & Torrie, 1984).

## Results

**Effect of timing of application of NAA and genotypes on root fresh weight, dry weight and root length:** RFW, RDW and RL in both years were significantly ($p \leq 0.05$) influenced by the combined effect of timing of application of NAA and genotypes (Table 1). In both years, maximum RFW was recorded in the treatment in which NAA was applied to ‘Gourav’ at 20 and 35 DAS, followed by NAA applied at the same DAS to ‘Sourav’ and ‘Agrahani’. Lowest values were observed in the control plot. However, maximum RDW (similarly significant values) was also recorded in ‘Gourav’ (when NAA was applied at 20 and 35 DAS) and ‘BAW 953’ (when NAA was applied at 35 and 50 DAS), followed by NAA applied at 20 and 35 DAS in ‘Sourav’ and ‘Agrahani’, while the lowest values were observed in the control plot. Longest roots were observed in ‘Gourav’ when NAA was applied at 20 and 35 DAS, followed by ‘BAW 953’ when NAA was applied at 35 and 50 DAS while shortest roots formed in the control plot in both years (Table 1).

**Table 1. Combine effect of time of application of NAA and wheat genotypes on root fresh weight, dry weight and root length at different growth stages of wheat is affected by.**

| Combine effect of time of application of NAA and genotypes | RFW (mg cc soil$^{-1}$) at 10 cm depth of upper soil | | RDW (mg cc soil$^{-1}$) at 10 cm depth of upper soil | | RL (m cc soil$^{-1}$) at 10 cm depth of upper soil | |
|---|---|---|---|---|---|---|
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| NAA at 20, 35 and 50 DAS x Kanchan | 0.98wx | 0.95x | 0.18z | 0.17z | 1.14y | 1.13y |
| NAA at 20, 35 and 50 DAS x Protiva | 2.15de | 2.17de | 0.85ijk | 0.88ij | 1.49n-q | 1.50n-q |
| NAA at 20, 35 and 50 DAS x Sourav | 1.59nop | 1.57nop | 0.65mno | 0.63m-p | 1.37u-w | 1.34u-w |
| NAA at 20, 35 and 50 DAS x Gourav | 2.20d | 2.17de | 1.13d | 1.06e | 1.77ef | 1.75ef |
| NAA at 20, 35 and 50 DAS x BAW 944 | 1.84i | 1.80ij | 0.88ij | 0.86ijk | 1.55h-m | 1.53h-m |
| NAA at 20, 35 and 50 DAS x BAW 953 | 2.00fgh | 1.98ghi | 0.85ijk | 0.88ij | 1.67g | 1.70g |
| NAA at 20, 35 and 50 DAS x BAW 994 | 1.63mno | 1.60mno | 0.63nop | 0.58pqr | 1.501-o | 1.4901-o |
| NAA at 20, 35 and 50 DAS x Akbar | 1.76ijk | 1.75i-l | 0.50stu | 0.48tuv | 1.61hi | 1.58h-k |
| NAA at 20, 35 and 50 DAS x Agrahani | 1.98fgh | 1.98fgh | 0.63nop | 0.61opq | 1.56h-l | 1.54h-l |
| NAA at 20, 35 and 50 DAS x Sonalika | 1.96gh | 1.94hij | 0.63nop | 0.60opq | 1.40s-v | 1.41s-v |
| NAA at 20 and 35 DAS x Kanchan | 1.70ilm | 1.65mn | 0.60opq | 0.63opq | 1.50m-p | 1.48n-r |
| NAA at 20 and 35 DAS x Protiva | 2.30c | 2.25cde | 1.05e | 1.03ef | 1.42r-u | 1.43r-u |
| NAA at 20 and 35 DAS x Sourav | 2.50b | 2.45bc | 1.40b | 1.53b | 1.79e | 1.80e |
| NAA at 20 and 35 DAS x Gourav | 2.65a | 2.58ab | 1.67a | 1.70a | 2.51a | 2.54a |
| NAA at 20 and 35 DAS x BAW 944 | 1.28st | 1.25stu | 0.53rst | 0.50stu | 1.55i-m | 1.53k-n |
| NAA at 20 and 35 DAS x BAW 953 | 1.15uv | 1.11uvw | 0.38wx | 0.35x | 1.63h | 1.61h |
| NAA at 20 and 35 DAS x BAW 994 | 1.48pqr | 1.46pqr | 0.95gh | 0.90hi | 1.80e | 1.79e |
| NAA at 20 and 35 DAS x Akbar | 1.53opq | 1.50opq | 0.63nop | 0.68mn | 1.59h-k | 1.58h-k |
| NAA at 20 and 35 DAS x Agrahani | 2.45bc | 2.45bc | 1.43b | 1.51b | 1.70g | 1.68g |
| NAA at 20 and 35 DAS x Sonalika | 1.08vw | 1.10uvw | 0.53rst | 0.50stu | 1.90d | 1.93d |
| NAA at 20 and 50 DAS x Kanchan | 1.30s | 1.28st | 0.50stu | 0.48tuv | 1.58h-k | 1.57h-k |
| NAA at 20 and 50 DAS x Protiva | 1.20tu | 1.18uvw | 0.35x | 0.33x | 1.312w | 1.32w |
| NAA at 20 and 50 DAS x Sourav | 2.48bc | 2.50b | 1.30c | 1.35c | 1.70fg | 1.72fg |
| NAA at 20 and 50 DAS x Gourav | 1.65mn | 1.68lmn | 0.50stu | 0.49stu | 1.47n-r | 1.48n-r |
| NAA at 20 and 50 DAS x BAW 944 | 1.30s | 1.28st | 0.70m | 0.68m | 1.58h-k | 1.59h-k |
| NAA at 20 and 50 DAS x BAW 953 | 1.43r | 1.45qr | 0.38wx | 0.39wx | 1.23x | 1.202x |
| NAA at 20 and 50 DAS x BAW 994 | 1.48pqr | 1.50opq | 0.56qrs | 0.55qrs | 1.59h-k | 1.60h-j |
| NAA at 20 and 50 DAS x Akbar | 1.03wx | 1.08vw | 0.29y | 0.28y | 1.42r-u | 1.41s-v |
| NAA at 20 and 50 DAS x Agrahani | 1.60mno | 1.59nop | 0.61nop | 0.63nop | 1.76ef | 1.78ef |
| NAA at 20 and 50 DAS x Sonalika | 0.95x | 0.98l-x | 0.18z | 0.18z | 1.58h-k | 1.56h-k |
| NAA at 35 and 50 DAS x Kanchan | 1.93h | 1.94h | 0.781 | 0.801 | 1.59h-k | 1.58h-k |
| NAA at 35 and 50 DAS x Protiva | 2.05fg | 2.00fgh | 0.86ijk | 0.85ijk | 1.50m-p | 1.53k-n |
| NAA at 35 and 50 DAS x Sourav | 2.08ef | 2.05fg | 1.03ef | 1.00ef | 1.05l-o | 1.02l-o |
| NAA at 35 and 50 DAS x Gourav | 1.98fgh | 2.0fgh | 0.81kl | 0.80kl | 1.42p-t | 1.41p-t |
| NAA at 35 and 50 DAS x BAW 944 | 1.52opq | 1.55pqr | 0.44vw | 0.43vw | 1.55h-m | 1.53k-n |
| NAA at 35 and 50 DAS x BAW 953 | 1.08vw | 1.03wx | 1.68a | 1.70a | 2.02b | 2.10b |
| NAA at 35 and 50 DAS x BAW 994 | 1.70 ilm | 1.68lmn | 0.90hi | 0.88ij | 1.535j-m | 1.55j-m |
| NAA at 35 and 50 DAS x Akbar | 1.80ij | 1.78ijk | 0.50s-u | 0.53rst | 1.57h-k | 1.58h-k |
| NAA at 35 and 50 DAS x Agrahani | 1.83i | 1.80ij | 0.83j-l | 0.84j-l | 2.02c | 2.05bc |
| NAA at 35 and 50 DAS x Sonalika | 1.75i-l | 1.76ijk | 0.60opq | 0.63nop | 1.35vw | 1.36vw |
| No NAA x Kanchan | 1.55pqr | 1.55pqr | 0.35x | 0.38wx | 1.53k-n | 1.56h-k |
| No NAA x Protiva | 1.76ijk | 1.75i-l | 0.50stu | 0.53rt | 1.44p-t | 1.41s-v |
| No NAA x Sourav | 1.08vw | 1.18uvw | 0.23yz | 0.22yz | 1.56h-l | 1.55j-m |
| No NAA x Gourav | 1.55pqr | 1.57pqr | 0.63nop | 0.62nop | 1.36t-v | 1.38t-v |
| No NAA x BAW 944 | 0.98l-x | 0.95x | 0.38wx | 0.35x | 1.42p-t | 1.44p-t |
| No NAA x BAW 953 | 2.00fgh | 1.98fgh | 0.98fg | 0.95gh | 1.69e | 1.68e |
| No NAA x BAW 994 | 1.45q-r | 1.56pqr | 0.68mn | 0.70lm | 1.90d | 1.89d |
| No NAA x Akbar | 1.65lmn | 1.70klm | 0.59pqr | 0.58pqr | 1.50o-s | 1.49o-s |
| No NAA x Agrahani | 1.08vw | 1.05wxy | 0.23yz | 0.24yz | 1.44p-t | 1.43p-t |
| No NAA x Sonalika | 1.40r | 1.43qrs | 0.46uv | 0.45uv | 1.42r-u | 1.41s-v |
| F-test | ** | ** | ** | ** | ** | ** |
| CV (%) | 3.55 | 3.15 | 4.35 | 3.75 | 1.48 | 1.50 |

NAA, 1-naphthaleneacetic acid; DAS, days after emergence; Y1, first year (2009-10); Y2, second year (2010-11); RFWT, root fresh weight; RDWT, root dry weight; RL, root length; mg, milligram; m, meter; cc, cubic centimeter

**Effect of timing of application of NAA and genotypes on TDM:** The TDM of wheat genotypes recorded at 40, 50, 60, 70, 80, 90 and 100 DAS were significantly ($p \leq 0.05$) influenced by the combined effect of timing of NAA application and genotypes (Tables 2, 3). Maximum TDM at 40 and 50 DAS was observed in 'BAW 944' when NAA was applied at 20 and 50 DAS. However, significantly similar and maximum TDM at 60 DAS was observed in 'Kanchan' and 'Sourav' when NAA was applied at 20, 35 and 50 DAS, as well as at 70 DAS in 'Sourav' when NAA was applied at 20 and 35 DAS (Table 2). In contrast, maximum and statistically similar TDM was recorded at 80, 90 and 100 DAS in 'BAW 994', 'Gourav' and 'Agrahani' with when NAA was applied at 20, 35 and 50 DAS while lowest TDM was observed in 'Sonalika' in the absence of NAA (control plot) (Table 3).

**Yield and yield-related attributes:** The combined effect of timing of NAA application and genotypes also significantly ($p \leq 0.05$) influenced GY and yield attributes (Table 4). Tallest plants formed when NAA was applied at 20, 35 and 50 DAS in 'BAW 994' followed by 'BAW 953' and 'BAW 994' while shortest plants formed in 'Agrahani' when NAA was applied at 20 and 50 DAS. 'Agrahani' produced highest number of spikes $m^{-2}$ after the application of NAA at 35 and 50 DAS, which was statistically similar to 'BAW 944' when NAA was applied at 20, 35 and 50 DAS. Fewest spikes $m^{-2}$ formed in 'Sonalika' with the application of NAA at 20 and 35 DAS (Table 4).

The application of NAA at 20 and 35 DAS to 'BAW 994', 'BAW 953' and 'Agrahani' produced significantly similar and maximum number of spikelets $spike^{-1}$ in both years, followed by the application of NAA at 20 and 50 DAS to 'BAW 953' and 'Sonalika'. The fewest number of spikelets $spike^{-1}$ were obtained in 'Sonalika' in the NAA-free treatment (Table 4). Genotypes, 'BAW 944' and 'BAW 953' showed significantly similar TGW when NAA was applied at 20 and 50 DAS, followed by 'Agrahani' exposed to NAA at 20, 35 and 50 DAS. Smaller grains were found in 'BAW 953' in the NAA-free treatment. While, 'BAW 953' produced highest GY when NAA was applied at 20, 35 and 50 DAS, which was statistically similar to the application of NAA at 20 and 35 DAS, and at 35 and 50 DAS in both 'BAW 994' and 'Protiva'. However, 'Sonalika' produced significantly lowest GY in all NAA treatments as well as in the control (Table 4).

## Discussion

**Soil nutrient status and climatological conditions during the experiment:** The soil nutrient status before sowing wheat in the experimental soils was sampled and analysed. Soil pH was 5.3 and organic matter was 1.2%. The pre-sowing total soil nitrogen (N) status was 0.08%, indicating that soil was deficient in soil N. Available K was 0.17 meq $100g^{-1}$ soil, and available P, S, Zn and B were 19.0, 5.5, 0.80 and 0.18 µg $g^{-1}$ soil, respectively. Based on the critical level of these plant nutrients, K, S, Zn and B were low, but P was high.

Temperature (maximum and minimum) fluctuations, rainfall, sunshine hours and relative humidity are the most important climatic factors for phenology, growth, and yield of wheat (Hossain *et al.*, 2013; Uddin *et al.*, 2016). The ideal temperature required for wheat is 20-25°C and an extreme temperature is 35°C (Tewolde *et al.*, 2006; Hossain & Teixeira da Silva, 2012, 2013). Relative to those findings, the weather conditions in our experimental period were recorded and found suitable for good wheat GY for all tested genotypes.

**NAA affected root growth, plant biomass and yield of wheat in our study**: PGRs are one of the most important factors used to induce higher yield in field crops. They regulate physiological processes and synthetic PGRs may enhance the growth and development of field crops thereby increasing total dry mass of field crops, but the timing of application of NAA is important to increase crop yield (Cho *et al*., 2008; Aslam *et al.*, 2010; Adam & Jahan, 2011; El-ghit, 2015; Islam & Jahan, 2016). In the present study, data on RFW, RDW, RL, TDM, GY and yield attributes of wheat genotypes were significantly ($p \leq 0.05$) influenced by the timing of application of NAA in both years (Tables 1 to 4). These results indicate that the application of NAA at different growth stages of wheat are more effective than the control.

Jahan & Adam (2013), who conducted a field experiment, to investigate the effect of various concentrations of NAA (0, 25, 50, 75, 100 mg $l^{-1}$) on the growth and yield components of 'BARI Gom 26', also noticed that the application of NAA at different concentrations effectively increased growth parameters and yield while plant height, number of tillers $plant^{-1}$ and number of leaves $plant^{-1}$ performed negatively in most cases with a few exceptions (7 and 14 DAS with 25 and 50 mg $l^{-1}$ NAA). However, 50 mg $l^{-1}$ NAA produced the highest TDM at all the stages of growth except at 21 and 28 DAS. In contrast, spike length, number of grains $spike^{-1}$ and 1000-seed weight increased following the application of any concentration of NAA. The number of spikes $m^{-2}$ and maximum yield (g $plant^{-1}$ and t $ha^{-1}$) increased significantly only after the application of 50 mg $l^{-1}$ NAA, 9.09% and 12.24% higher than the control, respectively. Their results indicated that the application of NAA at different growth stages of wheat were more effective for RFW, RDW, RL and TDM of wheat genotypes than the control. Similarly, Islam & Jahan (2016) also conducted a field experiment to determine the growth and yield responses of BARI Gom-26 following the application of three concentrations of NAA, i.e., no NAA, 25 mg $l^{-1}$ NAA and 50 mg $l^{-1}$ NAA, and four levels of N-fertilizer, namely without any N-fertilizer (F0), 50% of the recommended dose, 75% of the recommended dose and full recommended dose of urea and reported that the maximum number of tillers, TDM $plant^{-1}$ were obtained with 25 mg $l^{-1}$ NAA in combination with 50% N-fertilizer recorded at different days after spray. They also noticed that number of effective tillers $plant^{-1}$, TGW and GY (g $plant^{-1}$ and t $ha^{-1}$) increased significantly with 25 mg $l^{-1}$ NAA in combination with 75% N-fertilizer.

**Table 2. Combined effect of time of application of NAA and wheat genotypes on total biomass dry weight (TDM) of wheat genotypes recorded at 40, 50, 60 and 70 DAS.**

| Combine effect of time of application of NAA and genotypes | TDM ($g\ m^{-2}$) at different DAS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40 DAS | | 50 DAS | | 60 DAS | | 70 DAS | |
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| NAA at 20, 35 and 50 DAS x Kanchan | 42.7g-m | 43.0g-m | 81.3o-t | 83.3o-s | 321.0a | 323.9a | 481.7f-k | 485.0d-i |
| NAA at 20, 35 and 50 DAS x Protiva | 38.7k-r | 37.9k-r | 86.3m-r | 85.7n-r | 229.7n-p | 230.3n-p | 505.3cd | 503.3de |
| NAA at 20, 35 and 50 DAS x Sourav | 40.0h-p | 38.0k-r | 108.0f-i | 107.9f-i | 316.3ab | 318.5ab | 498.0d-f | 495.3d-g |
| NAA at 20, 35 and 50 DAS x Gourav | 41.0g-o | 40.0h-p | 81.3-t | 81.1o-t | 295.7c-e | 291.7d-f | 494.7d-g | 492.3d-h |
| NAA at 20, 35 and 50 DAS x BAW 944 | 52.0cd | 53.0cd | 119.d-f | 118.7d-f | 240.0mn | 238.3mn | 415.7e-s | 417.3o-s |
| NAA at 20, 35 and 50 DAS x BAW 953 | 39.7i-q | 40.0h-p | 124.0cd | 122.7c-d | 235.3m-o | 230.3n-p | 495.3d-g | 494.3d-g |
| NAA at 20, 35 and 50 DAS x BAW 994 | 28.3w-y | 28.9w-y | 89.3l-r | 91.0k-q | 226.3n-q | 227.0n-q | 406.3lm | 404.3st |
| NAA at 20, 35 and 50 DAS x Akbar | 42.0g-m | 41.7g-n | 85.7n-r | 84.7n-s | 216.3p-s | 217.7p-s | 434.0n-p | 432.7o-q |
| NAA at 20, 35 and 50 DAS x Agrahani | 39.0k-r | 39.4j-q | 114.3d-g | 115.3d-g | 237.0m-o | 238.3mn | 492.3d-h | 494.3d-g |
| NAA at 20, 35 and 50 DAS x Sonalika | 34.0o-w | 33.7e-x | 91.0k-q | 89.01l-r | 263.7jkl | 264.7jkl | 483.3e-j | 485.3d-i |
| NAA at 20 and 35 DAS x Kanchan | 28.0w-y | 28.7v-y | 81.0o-t | 83.3o-s | 227.0n-q | 227.3n-q | 400.3st | 400.7st |
| NAA at 20 and 35 DAS x Protiva | 28.7v-y | 28.6v-y | 105.3g-j | 106.0g-j | 276.3g-j | 279.3f-i | 468.0im | 462.7j-m |
| NAA at 20 and 35 DAS x Sourav | 30.0u-y | 31.0t-u | 67.0u | 70.0t-u | 234.0m-o | 233.3no | 542.7a | 540.0a |
| NAA at 20 and 35 DAS x Gourav | 40.0h-p | 39.3j-q | 104.3g-j | 103.3g-k | 306.3bc | 303.0bc | 503.3de | 500.7de |
| NAA at 20 and 35 DAS x BAW 944 | 35.7m-v | 33.7e-x | 89.01l-r | 89.7l-q | 267.3i-k | 269.7h-k | 425.7o-f | 427.7o-q |
| NAA at 20 and 35 DAS x BAW 953 | 45.0f-k | 46.6e-i | 136.0b | 140.0b | 259.0kl | 258.3kl | 428.0o-q | 431.7n-o |
| NAA at 20 and 35 DAS x BAW 994 | 46.3e-j | 46.7e-i | 77.7q-u | 76.0r-u | 192.7u | 199.7tu | 454.0mn | 453.7mn |
| NAA at 20 and 35 DAS x Akbar | 26.7xy | 28.0wxy | 97.0i-n | 97.3q-u | 234.7mno | 233.3no | 464.0j-m | 463.0j-m |
| NAA at 20 and 35 DAS x Agrahani | 47.0e-h | 47.3efg | 87.3m-r | 88.3l-r | 286.7e-g | 287.0e-g | 435.3n-p | 433.3o-p |
| NAA at 20 and 35 DAS x Sonalika | 53.0cd | 52.3cde | 84.7n-s | 83.3o-s | 151.3x | 161.0wx | 417.3o-s | 415.7e-s |
| NAA at 20 and 50 DAS x Kanchan | 39.3j-q | 39.4j-q | 140.0b | 149.3b | 259.3kl | 258.3kl | 459.7lm | 462.7j-m |
| NAA at 20 and 50 DAS x Protiva | 54.3cd | 53.0cd | 104.0g-j | 105.3g-j | 259.0kl | 258.3kl | 406.0r-t | 404.3st |
| NAA at 20 and 50 DAS x Sourav | 44.0f-l | 45.0f-k | 134.0bc | 139.3b | 279.3f-i | 275.8f-i | 402.3st | 401.7st |
| NAA at 20 and 50 DAS x Gourav | 63.5b | 65.0b | 103.3g-k | 104.7g-j | 240.0mn | 238.3mn | 400.7st | 403.7st |
| NAA at 20 and 50 DAS x BAW 944 | 75.3a | 76.0a | 166.7a | 170.0a | 291.7d-f | 290.0d-g | 427.7o-q | 430.3o-q |
| NAA at 20 and 50 DAS x BAW 953 | 47.3e-g | 46.7e-i | 97.3i-n | 99.3h-m | 287.0e-g | 283.3e-g | 463.0j-m | 365.3u |
| NAA at 20 and 50 DAS x BAW 994 | 52.3c-e | 53.0cd | 119.0d-f | 118.7d-f | 206.3s-u | 209.3r-t | 430.3o-q | 433.3o-p |
| NAA at 20 and 50 DAS x Akbar | 50.3d-f | 47.0e-h | 89.7l-q | 88.3l-r | 179.3v | 177.3v | 385.7t | 395.7st |
| NAA at 20 and 50 DAS x Agrahani | 55.0bc | 54.3cd | 104.7g-j | 105.7g-j | 209.0r-t | 210.0r-t | 403.7st | 401.7st |
| NAA at 20 and 50 DAS x Sonalika | 28.7v-y | 28.0w-y | 97.3i-n | 94.33j-o | 161.0wx | 164.7wx | 485.0d-i | 485.3d-i |
| NAA at 35 and 50 DAS x Kanchan | 32.7q-x | 32.0r-x | 85.3n-r | 85.7n-r | 221.3o-x | 221.7o-r | 460.7k-m | 462.7j-m |
| NAA at 35 and 50 DAS x Protiva | 36.3m-u | 35.7m-v | 72.0s-u | 70.0t-u | 236.3n-o | 238.3mn | 432.7o-q | 433.3o-p |
| NAA at 35 and 50 DAS x Sourav | 31.0t-u | 31.0t-y | 88.3l-r | 87.3m-r | 164.7wx | 169.7vw | 431.7n-o | 430.3o-q |
| NAA at 35 and 50 DAS x Gourav | 29.0v-y | 28.7v-y | 101.0h-l | 99.3h-m | 227.3n-q | 226.3n-q | 399.0st | 395.7st |
| NAA at 35 and 50 DAS x BAW 944 | 31.3s-y | 31.0t-y | 80.3p-t | 83.3o-s | 169.7vw | 168.7vw | 522.7bc | 525.7bc |
| NAA at 35 and 50 DAS x BAW 953 | 35.7m-v | 33.7e-x | 76.0r-u | 77.7q-u | 238.3mn | 237.0m-o | 540.0a | 542.7a |
| NAA at 35 and 50 DAS x BAW 994 | 41.7g-n | 42.0g-m | 110.7e-h | 108.0f-i | 209.3r-t | 209.0r-t | 494.3d-g | 495.3d-g |
| NAA at 35 and 50 DAS x Akbar | 28.0w-y | 28.7v-y | 105.7g-j | 104.3g-j | 199.7tu | 192.7u | 453.7mn | 454.0mn |
| NAA at 35 and 50 DAS x Agrahani | 37.3l-t | 37.97k-r | 85.7n-r | 85.3n-r | 213.0q-t | 211.3q-t | 476.3g-l | 472.7h-m |
| NAA at 35 and 50 DAS x Sonalika | 38.3k-s | 38.7k-r | 115.3d-g | 114.3d-g | 217.7p-s | 216.3p-s | 388.3t | 395.7st |
| No NAA x Kanchan | 33.7e-x | 34.7n-w | 137.3b | 139.0bc | 230.3n-p | 233.3no | 404.3st | 401.7st |
| No NAA x Protiva | 46.7e-i | 46.7e-i | 122.7c-d | 124.0cd | 290.0d-g | 291.7d-f | 401.7st | 406.0r-t |
| No NAA x Sourav | 28.00w-y | 28.0wxy | 107.7f-i | 106.0g-j | 221.7o-r | 221.3o-x | 395.7st | 400.3st |
| No NAA x Gourav | 35.7m-v | 35.7m-v | 94.33j-o | 93.0j-p | 269.7h-k | 267.3i-k | 365.3u | 368.3stu |
| No NAA x BAW 944 | 24.7y | 24.6y | 106.0g-j | 107.9f-i | 314.0ab | 316.3ab | 485.3d-i | 492.3d-h |
| No NAA x BAW 953 | 28.7v-y | 28.0w-y | 70.0t-u | 72.0s-u | 249.0lm | 245.0lm | 472.7h-m | 476.3g-l |
| No NAA x BAW 994 | 32.0r-x | 32.0r-x | 99.3h-m | 97.3i-n | 258.3kl | 263.7j-l | 433.3o-p | 432.7o-q |
| No NAA x Akbar | 39.0a-r | 39.3j-q | 118.7d-f | 118.7d-f | 303.0b | 300.0b | 462.7j-m | 464.0j-m |
| No NAA x Agrahani | 31.0t-y | 31.0t-y | 93.0j-p | 91.0k-q | 283.3e-g | 287.0e-g | 412.0q-s | 415.7e-s |
| No NAA x Sonalika | 34.7n-w | 35.7m-v | 83.3o-s | 84.7n-s | 233.3no | 230.3n-p | 352.0u | 350.0u |
| F-test | ** | ** | ** | ** | ** | ** | ** | ** |
| CV (%) | 9.33 | 9.34 | 6.74 | 6.75 | 3.32 | 3.36 | 2.50 | 2.50 |

Y1, first year; Y2, second year; TDM, total biomass dry weight; NAA, 1-naphthaleneacetic acid; DAS, days after emergence

**Table 3. Combined effect of time of application of NAA and wheat genotypes on total biomass dry weight (TDM) of wheat genotypes recorded at 80, 90 and 100 DAS.**

| Combine effect of time of application of NAA and genotypes | TDM (g m$^{-2}$) at different DAS | | | | | |
|---|---|---|---|---|---|---|
| | 80 DAS | | 90 DAS | | 100 DAS | |
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| NAA at 20, 35 and 50 DAS x Kanchan | 621.0c-g | 622.0c-g | 845.7e | 843.7e | 1065ghi | 1070ghi |
| NAA at 20, 35 and 50 DAS x Protiva | 584.71l-o | 580.0mno | 745.7t | 744.0t | 991.7stu | 980.7t-w |
| NAA at 20, 35 and 50 DAS x Sourav | 575.7m-o | 570.7m-p | 769.0o-r | 775.3n-p | 1065ghi | 1075hi |
| NAA at 20, 35 and 50 DAS x Gourav | 662.7b | 664.0b | 930.7a | 927.0a | 1179a | 1175a |
| NAA at 20, 35 and 50 DAS x BAW 944 | 598.3h-l | 594.3i-m | 824.7f-h | 833.7e-g | 1015o-q | 1020n-p |
| NAA at 20, 35 and 50 DAS x BAW 953 | 668.7ab | 667.3ab | 906.0b | 910.7b | 1145b | 1150b |
| NAA at 20, 35 and 50 DAS x BAW 994 | 566.0op | 570.7m-p | 805.0ij | 811.0si | 1082ef | 1080e-g |
| NAA at 20, 35 and 50 DAS x Akbar | 544.3q-s | 539.3rs | 797.0i-k | 792.7j-l | 1080e-g | 1070f-h |
| NAA at 20, 35 and 50 DAS x Agrahani | 681.7a | 675.7a | 916.7b | 906.7b | 1131b | 1136b |
| NAA at 20, 35 and 50 DAS x Sonalika | 613.0d-h | 617.3c-j | 783.7k-p | 784.0k-0 | 1020n-p | 1018n-p |
| NAA at 20 and 35 DAS x Kanchan | 629.0cd | 633.0c | 792.7jkl | 797.7jk | 1012pqr | 1015opq |
| NAA at 20 and 35 DAS x Protiva | 624.0c-f | 627.3cde | 839.7ef | 835.7efg | 1028m-o | 1025m-o |
| NAA at 20 and 35 DAS x Sourav | 657.3b | 640.3bc | 752.0st | 756.3r-t | 1073f-h | 1080e-g |
| NAA at 20 and 35 DAS x Gourav | 608.7e-i | 609.3e-i | 745.0t | 750.0t | 1036lm | 1030lm |
| NAA at 20 and 35 DAS x BAW 944 | 577.0m-o | 570.7m-p | 831.3efg | 833.7efg | 1098d | 1099d |
| NAA at 20 and 35 DAS x BAW 953 | 624.0c-f | 626.3c-e | 840.7e | 835.7efg | 1113c | 1115c |
| NAA at 20 and 35 DAS x BAW 994 | 590.0j-m | 570.7m-p | 811.0si | 805.0ij | 1049jk | 1051ijk |
| NAA at 20 and 35 DAS x Akbar | 608.7c-i | 609.7e-i | 776.7m-q | 775.3n-p | 1051i-k | 1055i-k |
| NAA at 20 and 35 DAS x Agrahani | 598.7h-l | 594.3i-m | 779.7l-p | 784.7k-o | 980.0t-v | 975.0vwx |
| NAA at 20 and 35 DAS x Sonalika | 556.0p-r | 570.7m-p | 419.7u | 420.7u | 934.7z | 945.7yz |
| NAA at 20 and 50 DAS x Kanchan | 586.3k-m | 580.0m-o | 843.7e | 845.7e | 968.7v-x | 967.7v-x |
| NAA at 20 and 50 DAS x Protiva | 606.3f-h | 609.7e-i | 775.3n-p | 769.0o-r | 946.0z | 956.0z |
| NAA at 20 and 50 DAS x Sourav | 580.0m-o | 579.3m-o | 744.0t | 745.0t | 970.0v-x | 971.0b-x |
| NAA at 20 and 50 DAS x Gourav | 589.3j-m | 589.7j-m | 784.7k-o | 783.7k-p | 1070fgh | 1075fgh |
| NAA at 20 and 50 DAS x BAW 944 | 628.7cd | 626.3c-e | 833.7e-g | 824.7f-h | 1103cd | 1107cd |
| NAA at 20 and 50 DAS x BAW 953 | 593.0i-m | 594.3i-m | 835.7e-g | 833.7e-g | 999.3rs | 997.7rs |
| NAA at 20 and 50 DAS x BAW 994 | 626.3c-e | 628.3c-e | 881.7c | 896.7bc | 1095de | 1098de |
| NAA at 20 and 50 DAS x Akbar | 579.7mno | 575.7m-p | 891.7bc | 888.0bc | 975.0v-x | 963.7v-x |
| NAA at 20 and 50 DAS x Agrahani | 609.3e-i | 608.7e-i | 869.7cd | 860.7cd | 1090de | 1095de |
| NAA at 20 and 50 DAS x Sonalika | 609.7e-i | 607.5e-i | 862.3d | 860.3d | 1047kl | 1050kl |
| NAA at 35 and 50 DAS x Kanchan | 633.0c | 627.3cde | 756.3r-t | 752.0st | 1063h-j | 1066h-j |
| NAA at 35 and 50 DAS x Protiva | 570.7m-p | 577.0m-o | 761.7q-s | 763.0u-s | 971.0b-x | 968.7v-x |
| NAA at 35 and 50 DAS x Sourav | 627.3c-e | 622.0c-g | 716.0u | 721.7u | 945.7yz | 963.7v-x |
| NAA at 35 and 50 DAS x Gourav | 594.3i-m | 589.7j-m | 721.7u | 716.0u | 767.0vx | 777.0vx |
| NAA at 35 and 50 DAS x BAW 944 | 628.7cd | 626.3c-e | 820.3gh | 822.3gh | 1046kl | 1048kl |
| NAA at 35 and 50 DAS x BAW 953 | 681.7a | 679.7a | 823.gh | 820.3gh | 997.7rs | 1000.7rs |
| NAA at 35 and 50 DAS x BAW 994 | 579.3m-o | 575.7m-o | 802.3i-j | 804.3i-j | 10321l-n | 10421l-n |
| NAA at 35 and 50 DAS x Akbar | 539.3s | 539.0rs | 878.7c | 880.7bc | 1088de | 1089de |
| NAA at 35 and 50 DAS x Agrahani | 622.0c-g | 627.3cde | 770.7o-r | 774.7n-q | 1002q-s | 1006p-s |
| NAA at 35 and 50 DAS x Sonalika | 589.7j-m | 589.3j-m | 719.0u | 720.0u | 972.3v-x | 971.0b-x |
| No NAA x Kanchan | 557.3p-q | 579.3m-o | 810.7hi | 820.3gh | 963.7v-x | 968.7v-x |
| No NAA x Protiva | 579.7m-o | 575.7m-o | 787.0k-m | 784.7k-o | 977.3h-w | 971.0b-x |
| No NAA x Sourav | 539.3rs | 540.3r | 741.3st | 745.0t | 960.7x | 963.7v-x |
| No NAA x Gourav | 576.7m-o | 576.7m-o | 763.0u-s | 761.7q-s | 959.7xy | 963.7v-x |
| No NAA x BAW 944 | 609.7e-i | 606.3f-h | 821.0gh | 810.7hi | 961.3wx | 975.0v-x |
| No NAA x BAW 953 | 579.3m-o | 580.0m-o | 774.7n-q | 770.7o-r | 965.7v-x | 963.7v-x |
| No NAA x BAW 994 | 578.7m-o | 593.0i-m | 751.7st | 752.0st | 967.7v-x | 968.7v-x |
| No NAA x Akbar | 603.7g-k | 608.7e-i | 820.3gh | 810.7hi | 992.7st | 997.7rs |
| No NAA x Agrahani | 617.3c-j | 622.0c-g | 768.0e-r | 770.7o-r | 969.3v-x | 971.0b-x |
| No NAA x Sonalika | 520.3stu | 510.3tu | 675.0v | 665.0vw | 1006p-s | 1002q-s |
| F-test | ** | ** | ** | ** | ** | ** |
| CV (%) | 1.60 | 1.58 | 1.05 | 1.05 | 1.82 | 2.00 |

Y1, first year; Y2, second year; TDM, total biomass dry weight; NAA, 1-naphthaleneacetic acid; DAS, days after emergence

**Table 4. Combined effect of time of application of NAA and genotypes on yield and yield-related attributes of wheat.**

| Combine effect of time of application of NAA and genotypes | Plant height (cm) | | Spikes $m^{-2}$ | | Spikelet $spike^{-1}$ | | TGW (g) | | GY ($t\ ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| NAA at 20, 35 and 50 DAS x Kanchan | 94.0a-e | 94.7a-c | 351b-c | 349c-e | 18.0b-g | 17.9b-h | 43.1a-d | 43.2b-h | 3.9st | 3.9q-s |
| NAA at 20, 35 and 50 DAS x Protiva | 92.3a-i | 92.7a-i | 294r-t | 319i-o | 17.0d-h | 17.3c-h | 42.9a-e | 42.3ab | 3.8s-u | 3.7uv |
| NAA at 20, 35 and 50 DAS x Sourav | 90.7b-j | 90.7b-j | 335c-j | 321h-o | 16.7e-h | 16.3f-h | 44.0a-c | 44.7a | 4.4hi | 4.3i-k |
| NAA at 20, 35 and 50 DAS x Gourav | 92.0a-i | 92.3a-i | 324f-o | 324h-o | 16.0jh | 16.7e-h | 42.3a-g | 42.5a-g | 4.1m-o | 4.2lmn |
| NAA at 20, 35 and 50 DAS x BAW 944 | 94.0a-e | 93.3a-g | 367ab | 379ab | 17.7b-h | 17.3c-h | 41.5d-h | 41.7d-h | 4.7c-e | 4.7bcd |
| NAA at 20, 35 and 50 DAS x BAW 953 | 96.0ab | 94.7a-c | 343c-d | 341d-h | 18.7a-c | 18.3a-e | 43.2b-h | 43.1a-d | 5.0a | 5.3a |
| NAA at 20, 35 and 50 DAS x BAW 994 | 97.3a | 94.7a-c | 304p-h | 304n-s | 18.0b-g | 18.3b-g | 42.2a-d | 42.3a-d | 3.9q-s | 4.0op |
| NAA at 20, 35 and 50 DAS x Akbar | 89.7c-j | 89.3c-j | 317j-p | 317i-o | 19.0a-d | 19.7ab | 42.5a-g | 42.4a-g | 3.7v | 3.7uv |
| NAA at 20, 35 and 50 DAS x Agrahani | 91.0b-j | 91.7h-i | 309n-r | 303o-s | 16.7e-h | 16.3e-h | 44.0a-g | 42.4a-g | 4.3j-l | 4.2l-n |
| NAA at 20, 35 and 50 DAS x Sonalika | 93.3a-g | 93.0a-h | 325e-n | 327g-n | 16.3f-h | 16.0f-h | 42.3ab | 42.9a-e | 2.5? | 2.6? |
| NAA at 20 and 35 DAS x Kanchan | 90.7b-j | 90.7b-j | 308n-r | 307m-p | 18.7a-c | 18.3a-e | 41.3b-h | 41.4b-h | 3.9r-t | 3.9r-t |
| NAA at 20 and 35 DAS x Protiva | 92.7a-i | 92.3a-i | 348b-d | 345c-g | 18.0b-g | 18.7a-c | 40.6b-h | 39.8p-h | 4.8bc | 4.7bcd |
| NAA at 20 and 35 DAS x Sourav | 93.0a-h | 93.3a-g | 285f-u | 316j-o | 18.7a-e | 18.3a-e | 41.2b-h | 41.1b-h | 3.8uv | 3.7uv |
| NAA at 20 and 35 DAS x Gourav | 93.0a-h | 93.3a-g | 308n-p | 313m-q | 17.3c-h | 17.0d-h | 43.2a-d | 43.3a-c | 3.6w | 3.7vw |
| NAA at 20 and 35 DAS x BAW 944 | 93.3a-g | 93.0a-g | 321g-p | 324h-o | 18.0b-g | 18.3b-f | 43.2a-d | 43.8a-c | 4.6b-f | 4.5def |
| NAA at 20 and 35 DAS x BAW 953 | 91.7a-i | 91.0b-j | 275u-u | 273u-v | 19.7ab | 20.0a | 41.7a-h | 41.5a-h | 4.1n-q | 4.0op |
| NAA at 20 and 35 DAS x BAW 994 | 94.7a-c | 94.0a-e | 291s-u | 289q-u | 20.3a | 20.3a | 43.1a-d | 43.5abc | 4.9abc | 4.8ab |
| NAA at 20 and 35 DAS x Akbar | 91.3b-i | 91.0b-j | 304p-s | 295p-t | 17.3c-h | 17.0d-h | 42.5a-g | 42.1a-g | 3.9q-s | 3.8s-u |
| NAA at 20 and 35 DAS x Agrahani | 90.7b-j | 90.8b-j | 329e-m | 328f-m | 19.3a-c | 19.0a-d | 42.4a-g | 42.7a-f | 3.8t-v | 3.8uv |
| NAA at 20 and 35 DAS x Sonalika | 92.7a-i | 92.6a-i | 267u | 263v | 15.7h | 15.5h | 43.9a-c | 43.83a-c | 2.3? | 2.4? |
| NAA at 20 and 50 DAS x Kanchan | 90.3b-j | 91.03b-j | 351bc | 349c-f | 18.7a-e | 18.3b-f | 40.9c-h | 40.5d-h | 4.4h-j | 4.3ijk |
| NAA at 20 and 50 DAS x Protiva | 91.7h-i | 91.0b-j | 317f-p | 316j-o | 17.9b-h | 18.0b-h | 41.4b-h | 41.2b-h | 4.1m-p | 4.1r-t |
| NAA at 20 and 50 DAS x Sourav | 89.3c-j | 88.7b-j | 315q | 313k-p | 17.3c-h | 17.7b-h | 39.8p-h | 39.6g-h | 4.2fg | 4.3fg |
| NAA at 20 and 50 DAS x Gourav | 87.3h-j | 88.3e-j | 308n-r | 307m-r | 18.0b-g | 18.3b-f | 40.6d-h | 40.5d-h | 4.4fg | 4.3jkl |
| NAA at 20 and 50 DAS x BAW 944 | 87.7g-j | 88.3e-j | 337c-h | 335l-k | 17.0d-h | 17.3c-h | 44.7a | 44.0a-c | 4.6fg | 4.5efg |
| NAA at 20 and 50 DAS x BAW 953 | 89.0c-j | 88.7b-j | 338c-g | 339e-i | 19.0 a-d | 19.7ab | 42.5a-g | 42.8a-e | 4.0p-s | 4.1n-q |
| NAA at 20 and 50 DAS x BAW 994 | 92.7a-i | 91.3b-i | 335e-j | 333e-k | 17.7b-h | 17.0b-h | 44.7a | 44.0a-c | 4.0p-s | 4.0p-s |
| NAA at 20 and 50 DAS x Akbar | 93.3a-g | 93.0a-g | 285p-u | 284s-u | 18.3b-f | 18.0b-g | 42.5a-g | 42.3a-g | 3.5wx | 3.7vw |
| NAA at 20 and 50 DAS x Agrahani | 85.3j | 85.4j | 332d-i | 331e-l | 16.3f-h | 16.7f-h | 42.1a-g | 42.3a-g | 4.3j-l | 4.2i-l |
| NAA at 20 and 50 DAS x Sonalika | 91.0b-j | 91.3b-i | 297q-t | 291q-u | 19.0a-g | 18.7a-g | 41.1b-h | 41.5b-h | 2.1? | 2.1? |
| NAA at 35 and 50 DAS x Kanchan | 91.0b-j | 91.3b-i | 317j-p | 317i-o | 18.0b-g | 18.7b-j | 42.4a-g | 42.4a-g | 4.6d-g | 4.7bcd |
| NAA at 35 and 50 DAS x Protiva | 89.3c-j | 89.7c-j | 307o-s | 277t-v | 19.0a-d | 18.7a-f | 42.7a-f | 42.3a-g | 4.7cde | 4.7bcd |
| NAA at 35 and 50 DAS x Sourav | 87.3h-j | 88.3e-j | 333c-k | 333e-k | 17.7b-h | 17.3b-f | 42.5a-g | 42.4a-g | 3.4wx | 3.5s-u |
| NAA at 35 and 50 DAS x Gourav | 88.7b-j | 88.7b-j | 323g-o | 323h-o | 16.7e-h | 16.5e-h | 43.83a-c | 43.5abc | 4.5p-s | 4.5p-s |
| NAA at 35 and 50 DAS x BAW 944 | 93.3a-g | 93.4a-g | 316k-p | 308m-q | 18.0b-g | 18.3b-g | 41.2b-h | 41.5b-h | 4.7cde | 4.7cde |
| NAA at 35 and 50 DAS x BAW 953 | 91.3b-i | 91.7b-i | 336e-i | 336e-j | 19.0a-d | 19.7ab | 41.2b-h | 41.5b-h | 4.1r-t | 4.0r-t |
| NAA at 35 and 50 DAS x BAW 994 | 91.3b-i | 91.0b-i | 320h-p | 320h-o | 18.7a-e | 19.0a-d | 42.3a-g | 42.4a-g | 4.7cde | 4.7bcd |
| NAA at 35 and 50 DAS x Akbar | 90.0c-j | 91.0c-j | 341c-f | 348c-f | 17.0d-h | 17.7d-h | 42.3a-g | 41.4a-g | 4.5p-s | 4.6o-s |
| NAA at 35 and 50 DAS x Agrahani | 88.0f-j | 88.3e-j | 372a | 389a | 17.3b-h | 17.7b-h | 42.7a-g | 42.1a-g | 4.3i-k | 4.2i-k |
| NAA at 35 and 50 DAS x Sonalika | 88.0f-j | 88.3e-j | 328e-m | 328f-m | 19.0a-d | 19.7ab | 42.4a-g | 42.87a-c | 2.5? | 2.2? |
| No NAA x Kanchan | 87.7g-j | 88.7g-j | 312m-q | 3091-q | 18.0b-g | 18.7ab | 41.3b-h | 41.5b-h | 3.3y | 3.2y |
| No NAA x Protiva | 91.0b-j | 90.9b-j | 329r-b | 292q-u | 17.0d-h | 17.3b-f | 40.5d-h | 41.5d-h | 3.5wx | 3.5wx |
| No NAA x Sourav | 93.7a-f | 92.7a-f | 348d-t | 348c-f | 17.0d-h | 17.7e-h | 39.6g-h | 39.7f-h | 3.8s-u | 3.9s-u |
| No NAA x Gourav | 88.3e-j | 89.0e-j | 316k-p | 315j-p | 18.7a-e | 18.37a-f | 39.6g-h | 39.0h | 2.8z | 2.9z |
| No NAA x BAW 944 | 90.0c-j | 91.0b-j | 360b | 364bc | 17.3b-f | 17.7b-h | 39.9p-h | 39.7f-h | 3.9st | 4.0p-s |
| No NAA x BAW 953 | 94.3a-d | 94.0a-e | 318i-p | 325g-n | 16.7e-h | 16.6e-h | 39.0h | 39.6gh | 3.7r-t | 3.8r-t |
| No NAA x BAW 994 | 92.7a-i | 93.0a-i | 309n-p | 3091-q | 17.0d-h | 17.3d-h | 39.7f-h | 39.0h | 3.1y | 3.1y |
| No NAA x Akbar | 87.0ij | 88.0ij | 319i-p | 319i-o | 17.3b-h | 17.7b-h | 41.5b-h | 41.7b-h | 4.0p-s | 4.1p-s |
| No NAA x Agrahani | 87.7g-j | 88.3g-j | 359b | 369bc | 16.7e-h | 16.3e-i | 40.2b-h | 40.3b-h | 3.9q-s | 3.8q-s |
| No NAA x Sonalika | 93.3a-d | 94.0a-e | 287p-u | 287r-u | 14.6hi | 15h | 40.3d-h | 40.7d-h | 2.3? | 2.1? |
| F-test | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| CV (%) | 3.13 | 2.19 | 2.81 | 3.73 | 1.62 | 1.89 | 3.58 | 3.40 | 1.77 | 2.0 |

Y1, first year; Y2, second year; NAA, 1-naphthaleneacetic acid; DAS, days after emergence; TGW, 1000-grain weight; GY, grain yield

The positive influence of NAA on the growth or productivity of different crops was confirmed by earlier studies. Bai *et al*. (1987) found that the application of eight foliar sprays of 25 mg $l^{-1}$ NAA at 7-day intervals positively improved seed yield and yield components of *Vigna radiata* (mung been or green gran). The number of pods $plant^{-1}$ was increased by spraying 40 mg $l^{-1}$ NAA on groundnut once at either 45 DAS or twice at 45 and 55 DAS (Devasenapathy *et al.*, 1987). Deotale *et al*. (1998) observed that gibberellic acid and NAA application on soybean produced the tallest plants, highest number of leaves $plant^{-1}$, number of branches $plant^{-1}$, leaf area, dry matter, days to maturity and seed yield with 100–400 mg $l^{-1}$ NAA. Application of NAA (4.5% w/v) applied at 200 ml $ha^{-1}$ in three split doses at 45, 90 and 135 DAS increased number of pods $plant^{-1}$, seeds $pod^{-1}$, TGW, biological yield and GY of chickpea by 12.50, 6.98, 9.59, 2.61 and 13.98%, respectively more than the control (Aslam *et al.*, 2010). The application of 100 and 200 mg $l^{-1}$ NAA to *Oryza sativa* (rice) increased GY $plant^{-1}$ by 27.67 and 6.85%, respectively in 'BRRI dhan-29', but the difference was not significant. However, in 'BRRI dhan-50', GY $plant^{-1}$ was reduced by 26.54% at 100 mg $l^{-1}$ NAA and by 27.67% at 200 mg $l^{-1}$ NAA, with 100 mg $l^{-1}$ NAA stimulating growth most (Adam & Jahan, 2011). Alam *et al*., (2002) noticed that NAA at 20 mg $l^{-1}$ enhanced the straw yield and GY of wheat cultivars 'Sarsabz', 'Soghat' and 'S-232'. NAA has been used to enhance the growth and yield of cereals by promoting and improved root system, resulting in more, straighter and thicker roots (Bakhsh *et al.,* 2011b ;Yan *et al.*, 2014; Basuchaudhuri, 2016). PGRs also significantly increased root growth (RDW) and promoted new roots in rice sprayed with 10 or 100 mg $l^{-1}$ NAA at the tillering stage (Raoofi *et al.*, 2014; Basuchaudhuri, 2016). El-ghit (2015) noticed that a foliar application of NAA reduced the harmful effects of salinity on *Rosmarinus officinalis* (rosemary) and improved growth by increasing the concentration of NAA up to 200 mg $l^{-1}$ but decreased growth at a higher concentration (300 mg $l^{-1}$).

## Conclusions

The findings of a two-year study revealed that the application of NAA (25 mg $l^{-1}$) at 20, 35 and 50 DAS were effective for growth, yield and yield attributes of 10 wheat genotypes. Maximum TDM at 40 and 50 DAS was obtained in 'BAW 944' when NAA was applied at 20 and 50 DAS, but highest TDM at 60 DAS was observed in 'Kanchan' and 'Sourav' when NAA was applied at 20, 35 and 50 DAS. TDM at 70 DAS were observed in 'Sourav' with the application of NAA at 20 and 35 DAS. When considering yield and yield attributes, 'BAW 994' and 'BAW 953' produced significantly similar and maximum GY when NAA was applied at 20, 35 and 50 DAS. Therefore, the application of NAA at 20, 35 and 50 DAS in all genotypes was more effective (i.e., better growth and yield) than the control plot, i.e., no NAA. Among the 10 tested genotypes, 'BAW 953' and 'BAW 994' responded best to NAA.

## Financial support

This research was conducted as part of a national research program of the Wheat Research Centre, BARI, Dinajpur, with the financial support of BARI from the annual research budgets.

## Acknowledgements

We are very grateful to Director General of BARI and Director of WRC, BARI to provide fund and uninterrupted support during the research trial.

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(Received for publication 6 February 2018)