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Exploring the Role of Foliar Application of Aspirin on Growth and Productivity of Wheat under Control and Rainfed Conditions

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A B S T R A C T

Aspirin (Acetylsalicylic acid) is an important signal molecule modulating plant responses to stress. Drought significantly decreased the growth rate and impaired the yield of wheat. Acetylsalicylic acid can improve the performance of wheat under both well-watered and drought conditions. Applying salicylic acid at a relatively low concentration positively impacted the physiological, yield, and growth parameters. In order to determine the effect of foliar application of Aspirin levels on growth, yield, and its components of wheat, two experiments, i.e., control and rainfed, were conducted to evaluate the effect of salicylic acid were carried out at glasshouse of Research Area, Department of Agronomy and university research farm Koont of PMAS-Arid Agriculture University Rawalpindi during cropping season 2019-20. Four treatments of Aspirin (Control, 120 mg/L, 180 mg/L, and 240 mg/L) for glasshouse (Control, 20 g/L, 30 g/L, 40 g/L) for rainfed were applied, which are to be known as As0, As1, As2, and As3 for both experiments. Foliar application of Aspirin solution sprayed at growth stage 37 on the Zadoks scale. Results of experiments revealed that for the 180mg/L of Aspirin (As2), improved growth parameters such as plant height, spike length, number of spikelets, and increased the wheat crop yield. In contrast, for the rainfed experiment, the plant height, spike length, number of spikelets, and increased yield were observed by applying 30 g/L (As2) of Aspirin, and the lowest results of these parameters were recorded in control treatment for both control and rainfed experiments. The overall results of this study showed that among the levels of Aspirin, the application of treatment As2 both for control and rainfed experiment, i.e., 180 mg/L for control and 30 g/L for rainfed Aspirin, have positively impacted the growth and yield parameters of wheat and bought improvement in wheat production under plant stress environment.

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INTRODUCTION

Wheat is grown worldwide and is one of the major food crops of Pakistan, and it only contributes about 8.9 % to agriculture and 1.6 % to the gross domestic product of Pakistan (Govt. of Pakistan 2019). As the people's main dietary requirement, wheat helps to remove the hunger of most of the global community (Zulfiqar *et al.,* 2020). The general economic productivity of the wheat for Pakistan is about 2.85 t ha^{-1}, which is too low compared to the developed countries that produce wheat worldwide (Govt. of Pakistan, 2017). Wheat varieties whose relative water content (RWC) and leaf turgor are higher have more tolerance to drought (Khakwani *et al.,* 2020). These varieties also provide more yield than varieties whose RWC and leaf turgor are lower (Marček *et al.,* 2019). The stomatal density, weight, area, and relative leaf water content are physiological changes in traits and have been considered important principles for yield progress (Reddy *et al.,* 2020).

The growth of wheat is highly influenced by climate change factors which include drought and other abiotic factors. From the last few years, rainfall is quite lower than the previous decade in most parts of the world. Due to this, the wheat produced in the rainfed area was 70 percent less than its average production. At pollination and grain forming stages, wheat plants are susceptible to water stress (Zahra *et al.,* 2021). That is why the means yield of wheat is highly affected if drought stress occurs at these stages. The physiological and biochemical characteristics of the plants are disturbed by drought stress, and it also affects normal productivity (Anjum *et al.,* 2011). The numerous physical characters of wheat, including dry matter production, assimilating area, relative water content (RWC), and chlorophyll content, are extremely affected by even moderate water shortage (Selim and Selim, 2019). The mechanism of the size of the plant, area of the leaf, and leaf area index help to regulate water use efficeincy, and it also reduces the injury causes by water shortage (Xu *et al.,* 2020). Drought stress is the most imperative abiotic stress that disturbs the growth of plants and increases yield losses. Drought causes a reduction in rainfed cereal production in many parts of the world (Farooq *et al.,* 2009; Hussain *et al.,* 2021).

Aspirin is the synthetic correspondent of salicylic acid (SA). In aqueous solutions, acetylsalicylic acid shows changes and is broken down into salicylic acid (Hussain *et al.,* 2018). Plants produce salicylic acid and it is a phenolic compound and has an important part in regulating many activities of plants such as germination of seeds, activities of enzymes, taking of ions and their transport, rate of photosynthesis, and growth of the plant (Liu *et al.,* 2016; Sharma *et al.,* 2020). Aspirin affects photosynthesis, increased cell division, absorption of nutrients, and maintenance of cellular membranes, as well as increased nitrate reductase, which increased representation of nitrates and content, total nitrogen and thus improves vegetative and flowery traits (Hamood and Majeed, 2017; Basit *et al.,* 2018). Apart from this function of growth promotion, it has been also reported that if we apply the spray of Aspirin on plants, it helps to improve the tolerance of the wheat plant to stresses, like salinity (Yusuf *et al.,* 2013) and drought stress (Kareem *et al.,* 2017). The shortage of water causes the abortion of grain, resulting in poor grain filling; thus, ultimately, the grain weight is reduced. (Shahbazi *et al.,* 2012). The main aim of the current research study is to check the growth and productivity of wheat under the treatments of acetylsalicylic acid (Aspirin) under control and in a rainfed environment.

METHODS AND MATERIAL

Planting Material

A well-known variety of wheat Pakistan-2013 is used as a test variety for this experiment whose seeds were taken from the National Agriculture Research Center, Islamabad, Pakistan. This variety is the medium maturing, best performing variety of rainfed areas. It is resistant to leaf rust, yellow rust, and stem rust race of Ug99. It has a 12 % of protein content.

Description of Experimental Site, Experimental Design and Treatments

The 1st experiment under control conditions was performed in a glasshouse of Research Area, Department of Agronomy, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan. It is situated at latitude 33°36'2.52"N and longitude 73°4'4.44"E. The climatic conditions of the area are sub-Tropical and sub-humid. The 2nd experiment was performed under rainfed conditions at university research farm Koont, located at Chakwal Road Rawalpindi. The latitude of the farm is 32.9303 °N, and its longitude is 72.8558 °E, and it is present at an altitude of 2,500 feet. The temperature of the farm touches 40 °C in summer while in winter temperature remains between 4 °C to 25 °C. The farm is located in an arid region where crops depend upon rainfall.

A control experiment was conducted in pots with a completely randomized design (CRD) comprised of four treatments of Aspirin (Control, 120 mg/L, 180 mg/L, and 240 mg/L known as As0, As1, As2 and As3. In contrast, the second experiment was conducted in the field with a randomized complete block design (RCBD) with four treatments of Aspirin (Control, 20 g/L, 30 g/L, 40 g/L) which are to be known as As0, As1, As2 and As3. We sprayed Aspirin solution at growth stage 37 on the Zadoks scale. We did the foliar spray of Aspirin by dissolving it in water with the help of a hand sprayer.

Parameters to be recorded

Data of growth parameters such as plant height (cm), number of tiller plant^{-1}, spike length (cm), number of spikelets spike^{-1} and days to maturity while for yield parameters which include, number of grain per spike, 1000-grains weight (g), Grain yield (kg ha-1), Biological yield (kg ha^{-1}) and Harvest index (%) were calculated. Recorded weather data for average monthly temperature (°C), rainfall (mm) and humidity (%) throughout the whole season during research work is shown in Figure 1.

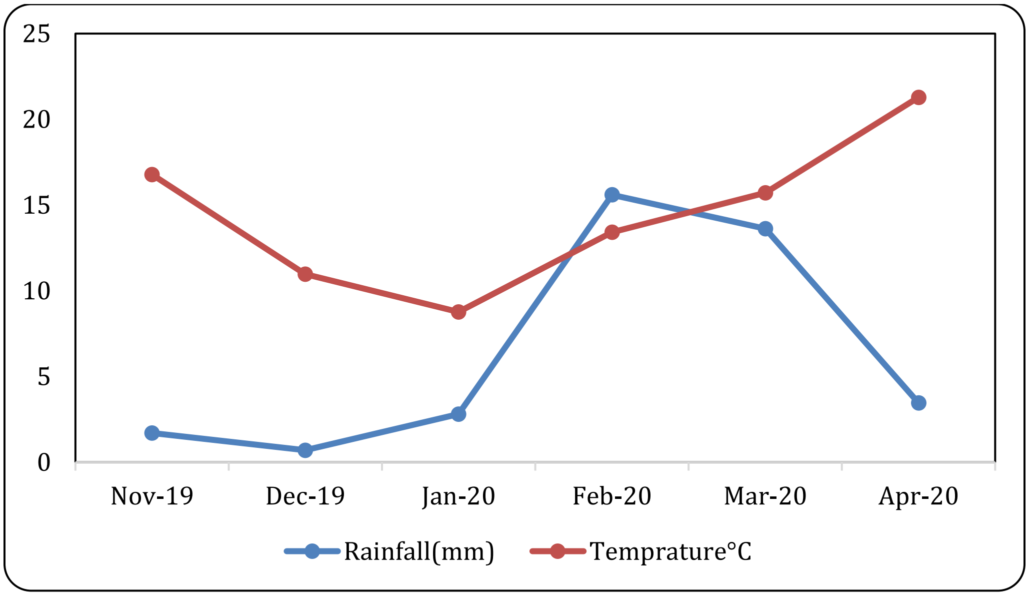

Figure1. Weather data during the cropping season.

Table 1. Soil analysis of experiment conducted for experiments.

Characteristics	Unit	Control Experiment		Rainfed Experiment	
		Values	Status	Values	Status
Texture			Loam		Sandy Loam
Ec	ds/m	1.20		0.73	
pH		7.7	Neutral	8.0	Neutral
Organic matter	%	2.27	Sufficient	0.84	Low
Phosphorus (P)	Ppm	71.5	Sufficient	10.81	Low
Potassium (K)	Ppm	94.5	Sufficient	98	Sufficient

Growth Parameters

Plant height (cm)

Separately ten plants were selected from each pot. Their height was measured with the scale in cm and their average height was calculated.

Number of tillers plant^{-1}

The number of tillers was counted and then their average was calculated.

Spike length (cm)

Ten plants were taken from every pot. Their spike length was measured in centimeters by using scale.

Number of spikelets spike^{-1}

We select 10 plants randomly and their number of spikelets was counted then their average was calculated.

Days to maturity

Days were counted from sowing to maturity.

Yield Parameters

1000-grains weight (g)

Spikes were harvested and a thousand-grains were counted from each pot. Weight was taken in grams while, 1000 grains were taken from each pot.

Grain yield (kg ha^{-1})

From each pot, plants were harvested. Spikes were threshed manually. Grains obtained from each pot were weighted and yield was calculated.

Biological yield (kg ha-1)

The biological yield was recorded per pot and it was converted in kg/ha.

Harvest index (%)

After obtaining biological and grain yield. The following formula calculated HI

HI= Grain yield / Biological yield ×100

Statistical Analysis

The analysis of variance, statistical analysis of collected data was computed. For this purpose, statistical software Statistics 8.1 was used. The treatment's effect on variables was tested and differences in treatments were compared using the LSD test at a probability level of 5 %. For growth parameters graph were ploted while for yield, data was presented in table.

RESULTS AND DISCUSSION

Growth Parameters

Plant Height

Plant height is a genetic character of plants. The height of the plant directly depends upon seedling vigor, environmental condition, water availability, and soil nutrient status in which the crop is grown. A significant difference was observed in plant height by applying Aspirin, as shown. We observed the highest plant height (95.7 cm) in a pot treated with foliar application As2 of Aspirin. (Figure 2) The minimum plant height (83.1 cm) in As0. The treatment As2 had a 13.16 % higher plant height over As0. Treatment As4 and As3 were statistically identical but had 9.3 % and 8.3 % higher plant height than As0. For the experiment conducted in the field, the plant height was increased significantly by applying Aspirin. By applying treatment As2 of Aspirin, the highest plant height (99.81 cm) was observed and the lowest (91.90 cm) was observed in As0. Treatment As2 shows 7 % more plant height as compare to As0. Treatment As3 and As1 were statistically the same, but they had 6 % and 5 % higher plant height over control.

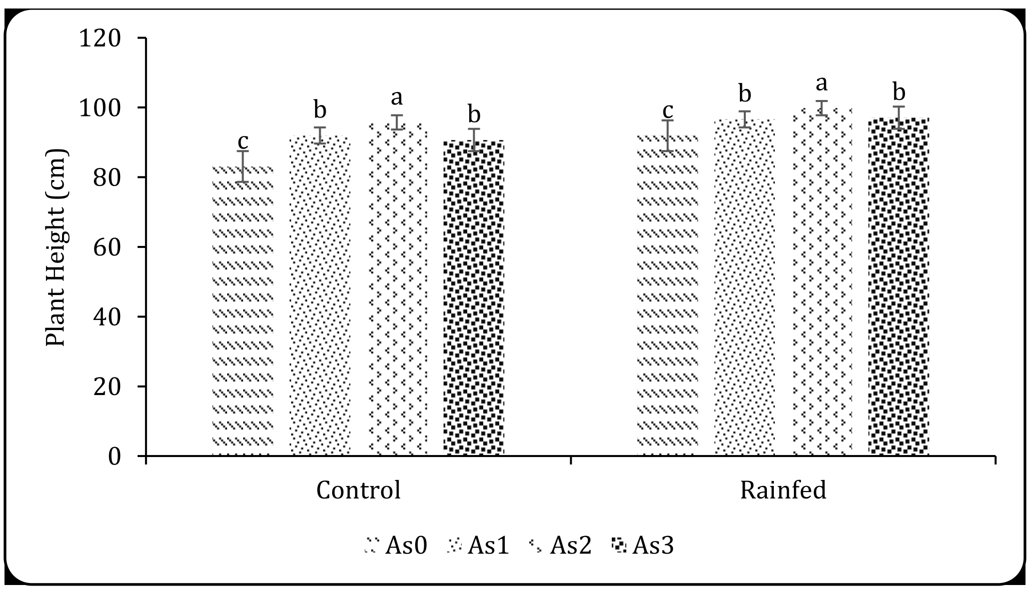

Figure 2. Plant Height of Wheat for Control and Rainfed Experiment.

Number of Tillers Plants-1

Tillering is the most important growth stage. The economic yield of crops depends upon the number of tillers. The graph given below represents the data collected from both experiments. The data recorded for number of tillers per plant was statistically non-significant, as shown below for the control and rainfed experiments (Figure 3).

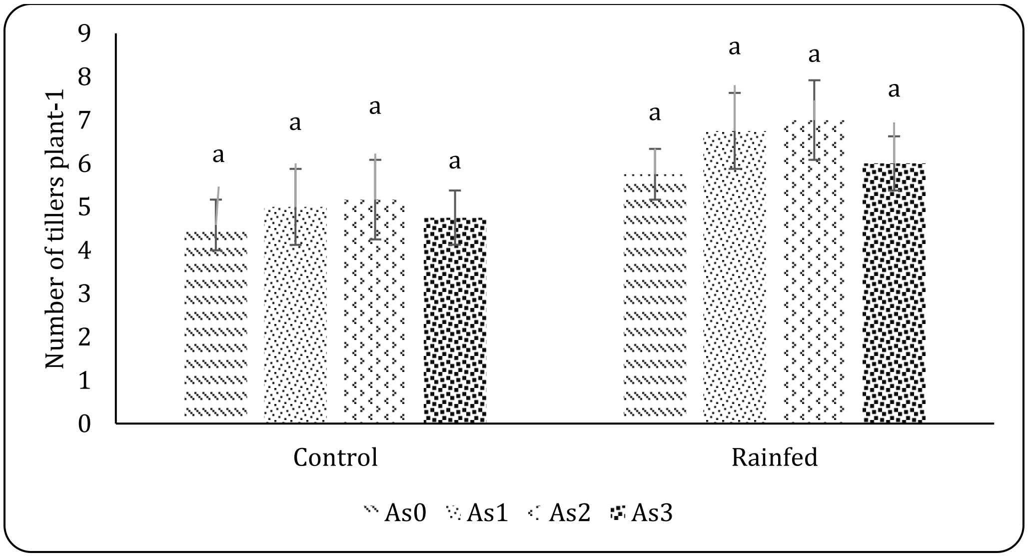

Figure 3. Number of Tillers Plants-1 of Wheat for Control and Rainfed Experiment.

Spike Length

The greater length of the spike, the more grains will be produced on each spike and the higher the wheat crop yield. The Spike length of wheat is affected by several environmental factors, including moisture and nutrients availability (Dakhim *et al.,* 2012). The data of spike length of wheat as influenced by treatment with different concentrations of Aspirin is signified in the graph. The highest spike length (15cm) was observed in As2, while the lowest (12cm) was observed in As0. Treatment As2 of shows a 20 % higher spike length than As0. Treatment As1 remaining at par with As3, but they had 5.97 % and 3.70 % higher spike length over treatment As0 (Figure 4). Treatment As3 and As0 were also statistically identical for the control experiment. Data presented for the rainfed experiment shows that spike length was significantly affected by Aspirin application. The maximum significant spike length (15.33cm) was observed in the plot, which was treated with As2 treatment, and the minimum (13.25 cm) was obtained in As0 treatment. 13 % higher spike length was obtained by the application of treatment As2 than As0. Statistical analysis of As1 and As2 shows identical; however, they possess 13 % and 11 % higher spike length over As0. Similarly, As3 and As0 were statistically identical, but As3 had a 2 % better spike length than As0 are shown below (Figure 4).

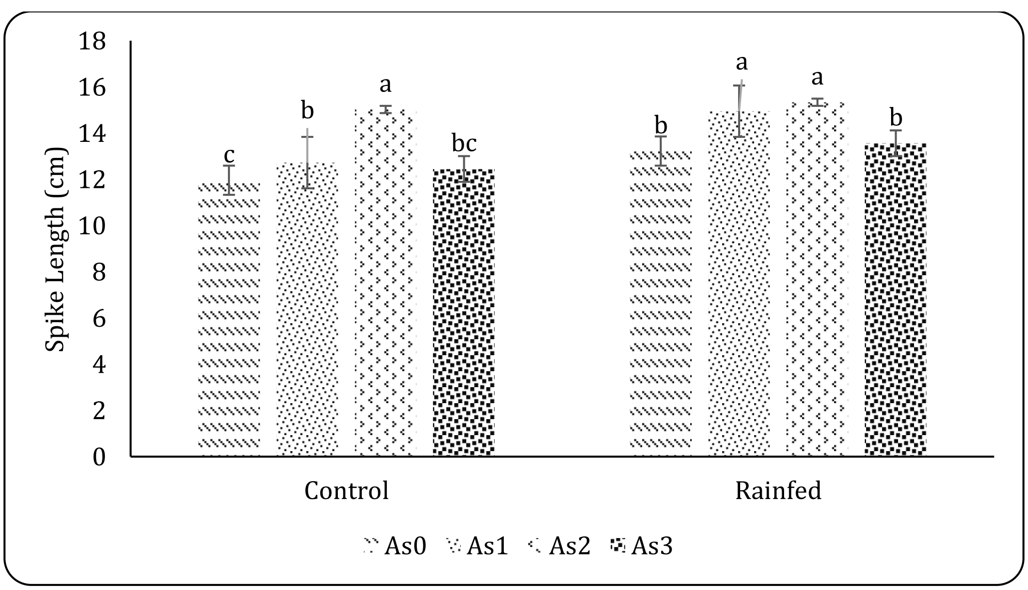

Figure 4. Spike Length of Wheat for Control and Rainfed Experiment.

Number of Spikelets per spike

Spikelets per spike are a hereditary character and are affected by many different factors such as temperature, moisture, and available nutrients (Goel and Singh, 2015). From the data presented below in figure 5, it was observed that the number of spikelets per spike was significantly different from each other in all the treatments. The maximum number of spikelets (17.3) was obtained by applying the As2 treatment of Aspirin, while the minimum number of spikelets (12.8) was observed in As0. Treatment As3 of Aspirin had 17.3 % more spikelets as compare to As0. Treatment As1 and As3 were similar while As1 had 13.86 % and As3 had 13.04 % higher spikelets over As0 (Figure 5).

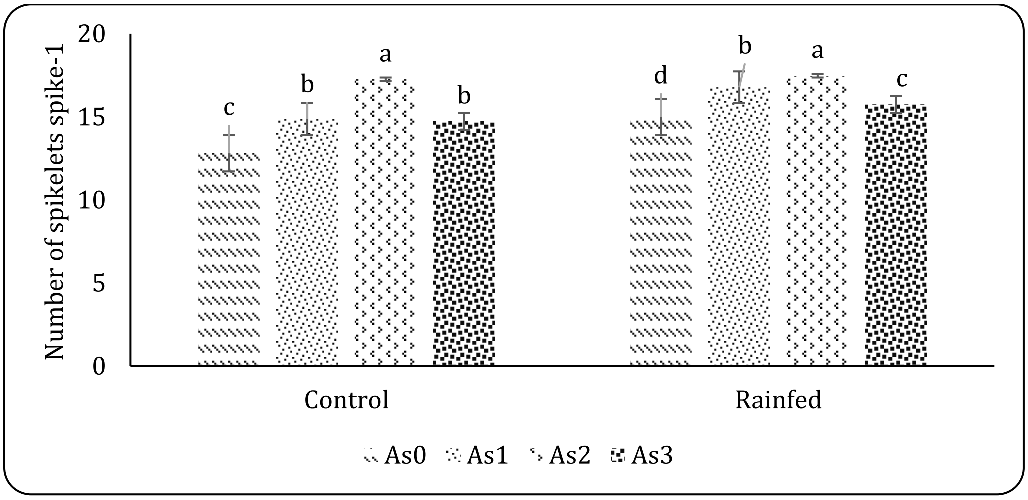

Figure 5. Number of Spikelets per spike of Wheat for Control and Rainfed Experiment

Days to Maturity

Aspirin foliar application had a significant effect on days to maturity. For the control experiment, the highest days for maturity (153.25) were taken by As2 of Aspirin, while the lowest days to maturity (149.5) were found in As0. Treatment As3, As2, and As1 were statistically at par with each other as shown in figure 6. However, Treatment As3 had taken 1.2 %, As2 had taken 2.4 %, and As1 had taken 2.1 % more days to mature than As0. While for the rainfed experiment, the highest days for maturity (165) were taken by treatment As2 while the lowest days to maturity (158) which As0 took. Treatment As2 was statistically at par with treatment As3 and As1. However, treatment As2 had taken 2.2 %, As3 had taken 1.5 %, and As1 had taken 1.2 % more days for maturity than As0. Treatment As1, As3, and As2 were also statistically the same, but they took 1.2 % and 1.5 % more days to mature compared to As0 (Figure 6).

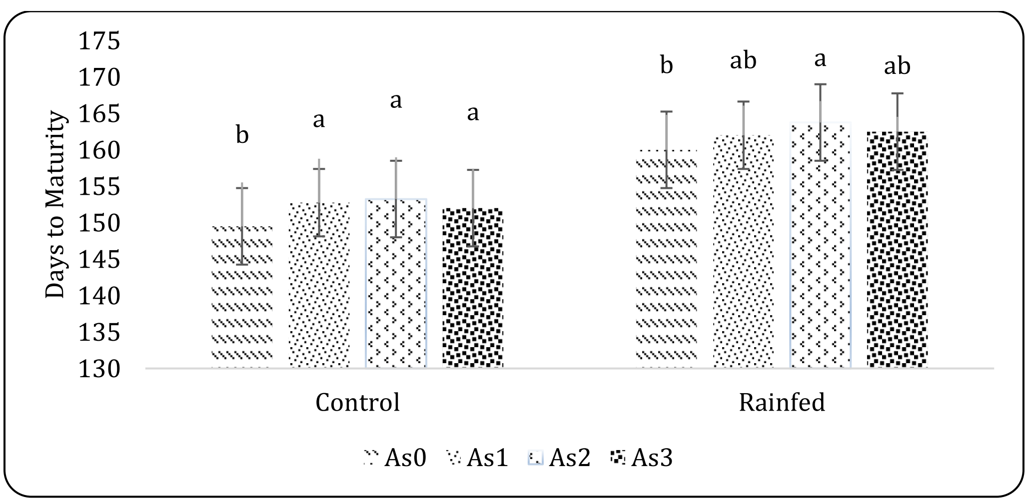

Figure 6. Days to maturity of Wheat for Control and Rainfed Experiment.

Yield Parameters

Number of Grains per spike

The number of grains helps to estimate the yield of a crop. The number of grains depends upon the length of the spike and the number of spikelets. From the analysis of the data presented in the table below, it is recorded that grain yield is positively affected by the application of Aspirin. A pot treated with 180 mg/L of Aspirin (As2) gave maximum significant grain per spike (24.27), and minimum (16.6) was found in control (As0) presented below in Table 2. The number of grains found in treatment As2 was 31.68 % higher than control. However, treatment As1 (120mg/L Aspirin) and As3 (240 mg/L Aspirin) were statistically similar. However, treatment As1 has 22.96 %, and As3 has 14.65 % more grains than As0. For the rainfed experiment, the application of Aspirin significantly increased the number of grains per spike was the maximum (43.30) grains per spike obtained from the plot, which was treated with As2, and in As0 minimum (36.53) grains per spike was founded. As2 contains 16 % more grains per spike than As0, while As1 has 16 % higher grains per spike compared to As0 (Table 2).

1000 Grain Weight

The observations regarding 1000 grain weight of wheat by applying different concentrations of Aspirin are shown below in the table 2. According to data recorded, there was a significant difference in the 1000 grain weight of plants by applying Aspirin. The application of As2 of Aspirin obtained the highest value (45.5 g), and the minimum value (35.1 g) was obtained in As0. The application of As2 of Aspirin has increased 22.8 % of grain weight over As0. Treatment As3 of Aspirin was remaining at par with control (As0) for the control experiment. For the rainfed experiment, it is observed from the data that the application of Aspirin effect the 1000 grain weight of wheat significantly. 74.22 g was the maximum 1000 grain weight obtained by applying treatment As2, and the minimum thousand-grain weight of 59.97 g was obtained in control treatment As0. 1000 grain weight was increased by 20 % compared to control with the As2 treatment of Aspirin. Treatment As3 and As1 (20 g/L Aspirin) have statistically similar 1000 grain weight, although both As1 and As3 contain 11 % and 10 % more thousand-grain weight than As0 (Table 2).

Biological Yield

A plant's biological yield depends upon the number of tillers and their weight, spike weight, and grain weight. The data about the biological yield of wheat for the control experiment as affected by applying Aspirin is given below in table 2. Maximum biological yield (58.87 g/pot) was recorded in pot treated with As2 of Aspirin. The least biological yield (47.17 g/pot) was recorded in the As0 treatment. The biological yield of treatment As2 was significantly 19.86 % higher than control treatment As0. The biological yield of treatment As2 and As1 was statistically identical, but thier biological yield was 4 % and 9 % higher than control (As0). The difference in biological yield of the different plants is due to differences in their tillers, spike, and grain weight. For the rainfed experiment, the data analysis shown below the experiment treatment As2 gave the highest (12050 kg/ha) biological yield while the lowest (9215 kg/ha) treatment As0 control. The biological yield obtained by the application of As2 was 23 % higher than that of As0. Treatment As3 was statistically identical with As2, but As3 had an 18 % higher biological yield than As0. Treatment As1 and As3 were statistically the same; both of these had 13 % and 18 % higher biological yield than As0.

Grain Yield

Grain yield is the main objective for which all the efforts were made. Grain yield can also be called economic yield. For the control experiment, higher grain yield (18.2 g/pot) of wheat was treated with foliar application of As2 of Aspirin, while the lowest yield (14.3 g/pot) was observed in As0 as shown in table 2. The maximum grain yield which was observed in As2 was 21 % more than As0. The grain yield of treatment As3 and As1 was statistically identical. However, treatment As3 had 5 %, and As1 had a 10 % higher grain yield than As0. Similarly, treatment As0 and As3 were statistically equal, but the grain yield of As3 was 4 % higher than As0. For the rainfed experiment, the highest yield (2470.8 kg/ha) was obtained in treatment As2 of Aspirin, while the lowest yield (2190.8 kg/ha) was observed in As0. By the application of As1 of Aspirin, grain yield was increased by 7 % over As0. While application of As2 of Aspirin gave 11 %, and the application of As3 of Aspirin gave 5 % more grain yield over As0, respectively.

Harvest Index

The percentage of economic yield to biological yield is termed as harvest index, and it specifies the ratio of assimilates transferred into profitable plant parts. The plant's physiological effectiveness and capability to transform the TDM into an economic product is recognized as the harvest index. The results for the harvest index are shown below in the table 2. The collected data for the control experiment shows that the harvest index was statistically non-significant. The highest harvest index (30.98) was disclosed in the As2 treatment of Aspirin that is statistically similar to as following As1, As3, and As0. At the same time, the lowest harvest index (30.25) was recorded in control (As0). The values of the harvest index for the rainfed experiment are statistically significant. The lowest harvest index (20.42) was recorded in the As3 treatment. The highest value (23.77) was recorded in As0 Treatment As2, and As3 are statistically similar but 13 % and 14 % less harvest index compared to As0. Treatment As1 and As0 were statistically at par, but their harvest index was higher than As1 and As4.

Table 2. Yield and yield parameters.

	Number of Grains Spike^{-1}		Biological Yield		Grain yield (kg ha^{-1})		1000 grain weight (grams)		Harvest index (%)	
	Control	Rainfed	Control	Rainfed	Control	Rainfed	Control	Rainfed	Control	Rainfed
As0	16.600 c	36.525 c	47.175 c	9218 c	14.275 c	2190.8 d	35.100 b	59.972 c	30.295 a	23.770 a
As1	21.550 b	40.850 b	52.000 b	10613 b	15.975 b	2362.0 b	41.950 a	66.738 b	31.010 a	22.271 a
As2	24.275 a	43.300 a	58.875 a	12050 a	18.200 a	2470.8 a	45.500 a	74.225 a	30.987 a	20.533 b
As3	19.450 b	36.800 c	49.375 bc	11363 ab	15.050 bc	2313.8 c	38.050 a	66.355 b	30.526 a	20.428 b
Mean	20.46875	39.36875	51.85625	10811	15.875	2334.35	40.15	66.8225	30.7045	21.7505

DISCUSSION

Growth Parameters

Our experiments demonstrated that drought causes a reduction in plant height as compared with usually grown wheat. This reduction was due to its effect on dry matter production. Our experiment alleviated the adverse effect caused by drought on plant height by applying salicylic acid. Our result were similar with Anosheh *et al.* (2012) that salicylic acid reduces the effect caused by drought and increases plant height compared to control. Rady and Mohamed (2015) also reported that the foliar application of salicylic acid improved the plant height. Saha *et al*. (2020) reported that a remarkable increase in plant height was occurred by applying Aspirin.

For the number of tillers per plant, spike length, and the number of spikelets spike-1, our results were in contrast with Amin *et al*. (2008), who found that salicylic acid's application improves the number of tillers of the wheat plant. This was because priming seed with Aspirin, while we had applied foliar application at GS 37 of Zadok scale at that stage tillering process, was complete. Similar results were obtained from Sharafizad *et al*. (2013); in their experiment, they founded that the drought decreased spike length, thousand-grain weight, harvest index, and biological yield while with the application of salicylic acid on wheat and a significant increase in spike length, thousand-grain weight and biological yield were obtained.

The resulting number of spikelet per spike and spike length obtained in this study is supported by Kareem *et al.* (2017), who found that the growth and yield of a crop were affected by drought but with the application of a salicylic acid number of spikelet and dry weight of the shoot and root of the wheat, the plant was improved. For the days to maturity, our results were the same as Baba *et al*. (2017), who found the foliar application of salicylic acid had a significant impact on days to maturity.

Yield Parameters

For the number of the grains per spike results of our experiment was same as obtained by Sofy (2015) who found that application of salicylic acid improves growth and yield component of wheat under different irrigated condition. Estaji and Niknam (2020) stated that plant height and number of grains are decreased by drought stress, but with the application of salicylic acid, plant height and number of grains were increased significantly. As for 1000-grain weight, our results were supported by Aminifard *et al*. (2020), who found in his experiment that grain weight was reduced by drought stress, but with the exogenous spray of the salicylic acid weight of grain and numbers are improved, they also founded that increase 1000 grain weight, and plant height was occurred by the application of salicylic acid. Hafez *et al*. (2020) founded that increase in thousand-grain weight, grains per spike, and the application of salicylic acid obtained harvest index.

Singh and Usha (2003) applied the salicylic acid on wheat in water deficit conditions and found the similar results for biological yield as obtained from our experiment. He also stated that this increase in wheat yield might be due to promoting Rubisco activity under water stress. Our results are similar to Bakry *et al*. (2012) they found that the application of salicylic acid improved the grain yield of linseed. Yadav *et al*. (2020) reported a remarkable increase in grain yield of pearl millet and wheat by applying salicylic acid. Hussain *et al*. (2018) obtained the similar results that indicate the increase in wheat yield by adding salicylic acid in nutritive solution. Tahir *et al*. (2009) stated that the highest harvest index results from the physiological potential of dry matter conversion into grain yield. Our results contradict Abd El-Mageed (2016), who found that salicylic acid application positively improves the harvest index.

CONCLUSION

The current research study concluded that among the levels of Aspirin, the application of treatment As2 both for control and rainfed experiment, i.e., 180 mg/L and 30 g/L of Aspirin for for control abd rainfed rerspectively, was most helpful and conveyed improvement in growth and yield parameters of wheat. However, a comprehensive evaluation of the effect and interaction of these nutrients on wheat crop production would help in understanding constraints of cultivation and decreasing the yield gap for food security. The responses of Aspirin in combination with multiple nutrient and different crops are required to be studied on a long-term basis for a better understanding of the nutrient dynamics of Aspirin.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS CONTRIBUTIONS

Conceptualization, I.A., M.J.K; methodology, S.A.S., M.J.K., I.A.; formal analysis, M.J.K.; investigation, M. J. K, M.F.A.; writing—original draft, M .F. A; writing—review and editing, M.F.A, A.W.; supervision, I. A.

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