Influence of Humic Acid and Foliar Salicylic Acid Application on Phenology and Dry Matter Partitioning of Maize

Sufyan Hameed[1], Shazma Anwar[1], Shahen Shah[1], Faiq Ahmad[1], Maaz Khan[1] and Sayed Zubair[2], Muzammil Aziz[2]

[1]Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar; Pakistan

[2]Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar; Pakistan

Correspondence: Shazma Anwar, anwar.shazma@gmail.com

Abstract: A field trial was conducted to investigate the influence of humic acid and foliar salicylic acid application on phenology and dry matter partitioning of maize at Agronomy Research Farm, The University of Agriculture, Peshawar during summer 2021. The experiment was laid out in a randomized complete block design using three replications. The experiment consisted of two factors: humic acid levels (0, 05, 10, and 15 kg ha^{-1}) and foliar salicylic acid application (0, 250, 500, and 750 mg L^{-1}). Humic acid was applied to the soil at the time of sowing, while salicylic acid was sprayed on foliar at V8 stage of the maize crop. Humic acid and salicylic acid application significantly affected the phenological and dry matter partitioning parameters of maize crops. Among the humic acid levels, maximum days to tasseling (59), days to silking (66), days to physiological maturity (104), leaf area plant^{-1} (5942 cm^2), leaf area index (3.0), stem dry weight at silking (89.4 g plant^{-1}), leaves dry weight at silking (33.7 g plant^{-1}), ear dry weight at silking (38.1 g plant^{-1}), stem dry weight at physiological maturity (63.2 g plant^{-1}), leaves dry weight at physiological maturity (30.9 g plant^{-1}) and ear dry weight at physiological maturity (159.0 g plant^{-1}) were recorded with the application of 15 kg ha^{-1}. In the case of the foliar salicylic acid application, maximum days to tasseling (59), days to silking (65), days to physiological maturity (104), leaf area plant^{-1} (6163 cm^2) and leaf area index (3.0), stem dry weight at silking (92.1 g plant^{-1}), leaves dry weight at silking (32.6 g plant^{-1}), ear dry weight at silking (37.1 g plant^{-1}), stem dry weight at physiological maturity (63.6 g plant^{-1}), leaves dry weight at physiological maturity (29.8 g plant^{-1}) and ear dry weight at physiological maturity (159.5 g plant^{-1}) were recorded with 750 mg L^{-1} foliar spray on maize. It was concluded from the experiment that application of humic acid at the rate of 15 kg ha^{-1} and foliar salicylic acid application at the rate of 750 mg L^{-1} delayed maize phenology and improved dry matter partitioning of maize at silking and physiological maturity stage in the agro-ecological conditions of the Peshawar region.

Keywords: Humic acid, Salicylic acid, Phenology, Dry matter partitioning, Maize

I. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in Pakistan after wheat and rice. In Khyber Pakhtunkhwa it ranked 2nd after wheat in its importance Iqbal et al. (2015). Maize contributes 3.4 percent to the value added in agriculture and 0.6 percent to GDP. Area under maize crop is 1418 thousand hectares with the total production of 8.465 million tons and national average yield of 5970 kg ha^{-1} (Pakistan Economic Survey, 2020-21). Although, soil and climatic conditions of Pakistan are highly favorable and high yielding varieties are also available, yet the yield of maize at farmer's field is low when compared with other maize-producing countries like the USA, Canada, and Egypt etc.

Humic acid is kind of macromolecular organic matter by anaerobic fermentation of plant residues (Susic et al., 2016). The addition of humic acid to fertilizer can substantially enhanced crop yield, soil physiochemical properties and improved soil adsorption capacity for NH_4^+, increase microbial activity and soil organic carbon and fix inorganic nitrogen into organic carbon nitrogen (Purwanto et al., 2021; Zhu and Peng, 2021). Combine application of humic acid with urea, the carboxyl group and phenolic hydroxyl group of humic acid interact with amide group of urea to forma complex with high stability, as a result of which NH_4^+ - N and NO_3 - N availability enhanced in soil and nitrogen use efficiency and decrease in nitrogen losses (Zhang et al., 2019) decreased phosphorus fixation, increased the efficiency of low and high solubility of phosphorus sources and as a result phosphorus use efficiency enhanced (Rosa et al., 2018; Shafi et al., 2020). It has been revealed that humic acid involved in improving several aspects of growth in essential agronomic crops like wheat, maize, rice and soybean (Rosa et al., 2018). Humic acid act as plant biostimulant which promote photosynthesis, decreases transpiration, stimulate root and shoot growth and promote resistance in plant against stress (Dantas et al., 2018; Xu et al., 2021).

Salicylic acid influences a vast array of plant processes from seed germination to growth and enhances the salt tolerance by improving the endogenous salicylic acid level (El-Mergawi and El-Wahed, 2020). Salicylic acid is a phenolic phytohormone that is widely present in plants and is considered to be an endogenous signaling substance (Arif et al., 2020; Klessig et al., 2018). As a signaling molecule SA play a significant role to regulate the defense system of plants against abiotic and biotic stresses also take part in plant growth and development, mineral absorption and transpotation, flowering, photosynthesis and transpiration (Cui et al., 2017; Ullah et al., 2019). Exogenously applied salicylic acid helps plants to regulate several functions including systemic acquired resistance (SAR) and plant resistance to environmental factors (Metraux, 2001) such as saltinity and drought in wheat (Arfan et al., 2007), chilling in maize (Farooq et al., 2008), heat tolerance in Cucumis sativus (Shi et al., 2006) and tolerance of cadmium toxicity (Krantev et al., 2006). Keeping in view the importance of humic acid and salicylic acid, the current research was conducted to study the influence of humic acid and salicylic acid on phenology and dry matter partitioning of maize in the agro-ecological conditions of the Peshawar region. The objectives of the experiment were (1) To examine the impact of various humic acid levels on maize phenology and dry matter partitioning, (2) To investigate the influence of foliar salicylic acid application on phenology and dry matter partitioning of maize and (3) finding the its interaction response on maize crop.

II. MATERIALS AND METHODS

Experimental site and treatments

An experiment entitled "influence of humic acid and foliar salicylic acid application on phenology and dry matter partitioning of maize" was conducted at Agronomy Research Farm, The University of Agriculture Peshawar in summer 2021. Experiment was performed with three replications using randomized complete block design (RCBD). Experiment was consisting of two factors: one was humic acid levels (0, 5, 10 and 15 kg ha^{-1}) and other was foliar salicylic acid (0, 250, 500 and 750 mg L^{-1}). Humic acid was applied at sowing time. For salicylic acid foliar sprays, required amount of water per plot was determined first and then suggested levels of salicylic acid was prepared and applied through knapsack sprayer at V8 stage of the crop. Nitrogen (N), phosphorus (P) and potassium (K) was applied at the rate of 160, 90 and 60 kg ha^{-1} from Urea, SSP (single super phosphate) and MOP (muriate of potash), respectively. Plot size was 5 m × 4.5 m (22.5 m^2) having six rows. Row to row and plant to plant distance was 75 cm and 25 cm, respectively. Thinning was carried out at four leaf stage of the crop to maintain recommended plant population. Weeds was controlled manually and recommended irrigation schedule was followed. Maize hybrid CS-200 was sown at the rate of 30 kg ha^{-1}.

Methodology of Data Recording

Days to tasselling

Data on days to tasseling was recorded by calculating days from the date of sowing to the date when 80 % plants produce tassels in each plot. The data was recorded by visual observations and average for a single reading.

Days to silking

Data on days to silking was recorded by calculating days from the date of sowing to the date when 80 % of plants reach a silking stage in each experimental plot. The data was recorded by visual observations and averages for a single reading.

Days to physiological maturity

Days to physiological maturity were calculated by counting the days from the date of sowing to the date when 80% of plants get mature in each experimental plot.

Leaf area plant^{-1} (LA)

Leaf length and width of all leaves of five randomly selected plants was measured in each treatment. Then the product of average leaf length, average leaf width and average number of leaves were multiplied with correction factor for calculation of leaf area plant^{-1}.

LA plant^{-1} (cm²) = leaf width × leaf length × No. of leaves × correction factor (0.75)

Leaf area index (LAI)

Leaf area index was recorded by dividing the product of leaf area plant^{-1} (cm²) and number of plants m^{-2} with ground area as follow.

LAI= Leaf area/ground area

Dry matter partitioning at silking (g)

Data concerning dry matter partitioning was calculated at silking stage. Five plants at silking stage were harvested from each plot. Leaves, stalk and ears were separated. The materials were sun dried and weighed separately by electronic balance and then dry weight of leaves, stem and ears plant^{-1} were determined.

Dry matter partitioning at physiological maturity (g)

Data concerning dry matter partitioning was calculated at physiological maturity stage. Five plants at maturity stage were harvested from each plot. Leaves, stem and ears were separated. The materials were sun dried and weighed separately by electronic balance and then dry weight of leaves, stalk and ears p1ant^{-1} were determined.

Statistical analysis

Data was statistically examined by using analysis of variance techniques recommended for the randomized complete block design. Upon significant F-test results, means was compared using least significance difference test (Steel and Torrie, 1984).

III. RESULTS

Days to tasseling

Data regarding days to tasseling of maize as affected by humic acid and salicylic acid is shown in Table 1. Humic acid and salicylic acid significantly affected tasseling of maize crop, while their interaction was found non-significant. Among the humic acid levels, delayed tasseling (59 days) was recorded with application of 15 kg ha^{-1}, followed by 10 and 5 kg ha^{-1} (58 and 57 days) respectively. Early tasseling (57 days) was recorded when no humic acid was applied. In case of the salicylic acid, late tasseling (59 days) was noted with addition of 750 mg L^{-1}, followed by 500 and 250 mg L^{-1} (58 days), while early tasseling (56 days) was recorded without application of salicylic acid.

Days to silking

Days to silking of maize as affected by humic acid and salicylic acid is shown in Table 1. Humic acid and salicylic acid significantly affected silking of maize crop, while their interaction was found non-significant. Among the humic acid levels, delayed silking (66 days) was recorded with application of 15 kg ha^{-1}, followed by 10 and 5 kg ha^{-1} (64 days). Early silking (63 days) was recorded when no humic acid was applied. In case of the salicylic acid, late silking (65 days) was noted with addition of 750 mg L^{-1}, followed by 500 and 250 mg L^{-1} (64 days), while early silking (56 days) was recorded without application of salicylic acid.

Days to physiological maturity

Days to physiological maturity of maize as affected by humic acid and salicylic acid is shown in Table 1. Humic acid and salicylic acid significantly affected physiological maturity of maize crop, while their interaction was found non-significant. Humic acid application at the rate of 15 kg ha^{-1} delayed physiological maturity (104 days), which is statistically similar with the application of 10 kg ha^{-1} (103 days), while early physiological maturity (102 days) was noted when no humic acid was applied, which is statistically same with 5 kg ha^{-1} (103 days). Salicylic acid addition at the rate of 750 mg L^{-1} reported late physiological maturity (104 days), followed by 500 and 250 mg L^{-1} (103 days), while early physiological maturity (101 days) was recorded without application of salicylic acid.

Leaf area plant^{-1} (cm^2)

Leaf area plant^{-1} of maize as affected by humic acid and salicylic acid is shown in Table 1. Humic acid and salicylic acid significantly affected leaf area plant^{-1} of maize crop, while their interaction was found non-significant. Among the humic acid levels, maximum leaf area plant^{-1} (5942 cm^2) was recorded with application of 15 kg ha^{-1}, followed by 10 and 5 kg ha^{-1} (5592 and 5259 cm^2) respectively. Minimum leaf area plant^{-1} (4900 cm^2) was recorded when no humic acid was applied. In case of the salicylic acid, highest leaf area plant^{-1} (6163 cm2) was noted with addition of 750 mg L^{-1}, followed by 500 and 250 mg L^{-1} (5446 and 5332 cm^2) respectively, while lowest leaf area plant^{-1} (4752 cm^2) was recorded without application of salicylic acid.

Leaf area index

Leaf area index of maize as affected by humic acid and salicylic acid is shown in Table 1. Humic acid and salicylic acid significantly affected leaf area index of maize crop, while their interaction was found non-significant. Among the humic acid levels, maximum leaf area index (3.0) was recorded with application of 15 kg ha^{-1}, followed by 10 and 5 kg ha^{-1} (2.8 and 2.6) respectively. Minimum leaf area index (2.3) was recorded when no humic acid was applied. In case of the salicylic acid, highest leaf area index (3.0) was noted with foliar application of 750 mg L^{-1}, followed by 500 and 250 mg L^{-1} (2.7 and 2.6) respectively, while lowest leaf area index (2.3) was recorded without application of salicylic acid.

Table 1. Days to tasseling, days to silking, days to physiological maturity, leaf area plant^{-1}, and leaf area index of maize as affected by humic acid and foliar salicylic acid application.

	Parameters				
Humic acid (kg ha^{-1})	Days to tasseling	Days to silking	Days to physiological maturity	Leaf area plant^{-1} (cm^2)	Leaf area index (LAI)
0	57 c	63 c	102 c	4900 d	2.3 c
5	57 c	64 b	103 b	5259 c	2.6 b
10	58 b	64 b	103 b	5592 b	2.8 ab
15	59 a	66 a	104 a	5942 a	3.0 a
LSD $_{(0.05)}$	0.85	0.84	0.96	332.5	0.24
Salicylic acid (mg L^{-1})					
0	56 c	63 c	101 c	4752 c	2.3 c
250	58 b	64 b	103 b	5332 b	2.6 b
500	58 b	64 b	103 b	5446 b	2.7 b
750	59 a	65 a	104 a	6163 a	3.0 a
LSD $_{(0.05)}$	0.85	0.84	0.96	332.5	0.24
Interaction					
HA × SA	NS	NS	NS	NS	NS

HA: humic acid, SA: salicylic acid, NS: non-significant

Stem dry weight at silking stage (g plant^{-1})

Data regarding stem dry weight at silking stage of maize as affected by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on stem dry weight at silking stage. Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, maximum stem dry weight at silking (89.4 g) was recorded with the application of 15 kg ha^{-1}, while minimum (80.3 g) was recorded when not treated with humic acid. In case of the salicylic acid, heaviest stem dry weight at silking (92.1 g) was recorded with foliar application of 750 mg L^{-1}, whereas lightest stem (78.9 g) was noted when no salicylic acid was applied.

Leaves dry weight at silking stage (g plant^{-1})

Data regarding leaves dry weight at silking stage of maize as affected by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on leaves dry weight at silking stage. Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, maximum leaves dry weight at silking (33.7 g) was recorded with the application of 15 kg ha^{-1}, while minimum (27.5 g) was recorded when not treated with humic acid. In case of the salicylic acid, highest leaves dry weight at silking (32.6 g) was recorded with foliar application of 750 mg L^{-1}. Lowest leaves dry weight at silking (28.2 g) was noted when no salicylic acid was applied, which is statistically similar with the salicylic acid foliar application at the rate of 250 mg L^{-1} (29.1 g).

Ear dry weight at silking stage (g plant^{-1})

Data regarding ear dry weight at silking stage of maize as affected by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on ear dry weight at silking stage. Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, maximum ear dry weight at silking (38.1 g), was recorded with the application of 15 kg ha^{-1}, while minimum (32.0 g) was recorded when not treated with humic acid. In case of the salicylic acid, highest ear dry weight at silking (37.1 g) was recorded with foliar application of 750 mg L^{-1}. Lowest ear dry weight at silking (32.7 g) was noted when no salicylic acid was applied, which is statistically similar with the salicylic acid foliar application at the rate of 250 mg L^{-1} (33.5 g).

Stem dry weight at physiological maturity (g plant^{-1})

Data regarding stem dry weight at physiological maturity of maize as influenced by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on stem dry weight at physiological maturity.

Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, highest stem dry weight at physiological maturity (63.2 g) was recorded with the application of 15 kg ha^{-1}, while lowest (54.4 g) was recorded when not treated with humic acid. In case of the salicylic acid, heaviest stem dry weight at physiological maturity (63.6 g) was recorded with foliar application of 750 mg L^{-1}, whereas lightest stem (52.2 g) was noted when no salicylic acid was applied.

Leaves dry weight at physiological maturity (g plant^{-1})

Data about leaves dry weight at physiological maturity of maize as affected by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on leaves dry weight at physiological maturity. Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, maximum leaves dry weight at physiological maturity (30.9 g) was recorded with the application of 15 kg ha^{-1}, while minimum (25.0 g) was recorded when not treated with humic acid. In case of the salicylic acid, highest leaves dry weight at physiological maturity (29.8 g) was recorded with foliar application of 750 mg L^{-1}. Lowest leaves dry weight at physiological maturity (25.7 g) was noted when no salicylic acid was applied, which is statistically similar with the salicylic acid foliar application at the rate of 250 mg L^{-1} (26.5 g).

Ear dry weight at physiological maturity (g plant^{-1})

Data regarding ear dry weight at physiological maturity of maize as affected by humic acid and salicylic acid is shown in Table 2. Humic acid and salicylic acid had significant effect on ear dry weight at physiological maturity. Interaction between humic acid and salicylic acid was found non-significant. Among the humic acid application, maximum ear dry weight at physiological maturity (159.0 g), was recorded with the application of 15 kg ha^{-1}, while minimum (137.6 g) was recorded when not treated with humic acid. In case of the salicylic acid, highest ear dry weight at physiological maturity (159.5 g) was recorded with foliar application of 750 mg L^{-1}. Lowest ear dry weight at physiological maturity (137.6 g) was noted when no salicylic acid was applied.

Table 2. Dry matter partitioning at silking and physiological maturity stage of maize as affected by humic acid and foliar salicylic acid application.

	Dry matter partitioning at silking stage (g plant^{-1})			Dry matter partitioning at physiological maturity (g plant^{-1})		
Humic acid (kg ha^{-1})	Stem dry weight	Leaves dry weight	Ear dry weight	Stem dry weight	Leaves dry weight	Ear dry weight
0	80.3 c	27.5 d	32.0 d	54.4 d	25.0 d	137.6 d
5	83.8 b	28.8 c	33.2 c	57.3 c	26.2 c	143.6 c
10	85.1 b	31.3 b	35.8 b	60.0 b	28.6 b	150.0 b
15	89.4 a	33.7 a	38.1 a	63.2 a	30.9 a	159.0 a
LSD $_{(0.05)}$	2.2	1.2	1.2	2.7	1.1	3.4
Salicylic acid (mg L^{-1})						
0	78.9 d	28.2 c	32.7 c	52.2 c	25.7 c	137.6 d
250	82.7 c	29.1 c	33.5 c	57.1 b	26.5 c	143.1 c
500	84.9 b	31.3 b	35.8 b	61.9 a	28.6 b	149.8 b
750	92.1 a	32.6 a	37.1 a	63.6 a	29.8 a	159.5 a
LSD $_{(0.05)}$	2.2	1.2	1.2	2.7	1.1	3.4
Interaction						
HA × SA	NS	NS	NS	NS	NS	NS

HA: humic acid, SA: salicylic acid, NS: non-significant

IV. DISCUSSION

Phenology not only influence flora and fauna grow or survive in their environments but it also affects our food supply. Application of humic acid and foliar salicylic acid significantly affected days to tasselling, silking and physiological maturity of maize crop, while their interactions were found non-significant. With the application of humic acid, late tasselling, silking and physiological maturity were noted with 15 kg ha^{-1}, while early tasselling, siliking and physiological maturity were reported when no humic acid was applied. The underlying reason for it may be that humic acid positively accelerated plant physiology, plant dry matter production, lateral roots initiation, cell respiration and hormonal activities, and nutrients uptake by plant cells (Puglisi et al., 2009). The delayed phenology may be due to higher available moisture and increased fertility level (both macro and micro nutrients along with organic matter) of the soil during crop growth because of humic acid application (Santa and Shrestha, 2014; Khan and Jan, 2017). As humic acid is a slow release fertilizer of nitrogen; the plants remained green and succulent for a prolonged period with increased chlorophyll content (Khan et al., 2014). In case of the salicylic acid, delayed tasselling, silking and physiological maturity were recorded with application of 750 mg L^{-1}, while early tasselling, siliking and physiological maturity were observed when no salicylic acid was applied. Delayed phenology may be due to enhancement of biochemical and physiological processes (Fariduddin et al., 2003) with foliar application of salicylic acid. Another possible cause is the application of salicylic acid enhanced the growth of crop (Sibgha et al., 2013) resulting in delay in phenological parameters. Foliar application of chemicals stimulates the physiological and metabolic processes which enhance vegetative growth and delayed phenology (Fariduddin et al., 2003). Our outcomes are in line with the results of Rehman and Khalil (2016) who stated that days to 50% flowering and days to maturity of canola were delayed with the foliar application of salicylic acid.

Leaf area is a vital aspect to assess several parameters of crop plants like canopy, photosynthesis and evapotranspiration (Ahmad et al., 2015). Leaf area $plant^{-1}$ and leaf area index (LAI) of maize were significantly affected with humic acid and salicylic acid. Humic acid applied at the rate of 15 kg ha^{-1} recorded maximum leaf area $plant^{-1}$ and leaf area index (LAI) of maize. The increased levels of humic acid might have improved maize growth as a result of improved nutrition and thus helped in expanding the leaf area and increasing leaves number (Atiyeh et al., 2002) as it led towards higher nitrogen concentration in its aerial parts as well as within the roots (Tan, 2003) which finally also improved LAI. Another possible cause is that the use of humic acid increased dry matter of leaves as a result of sustaining photosynthetic machinery of plants (Sharif et al., 2002; Turkmen et al., 2004) and providing macro as well as micro nutrients (Khaled and Fawy, 2011). The most valid reason for increased LAI may be the greater photo-assimilation and nutrients availability to maize plants as a result of humic acid application (Figliolia et al., 1994; Khaled and Fawy, 2011). These results have been augmented by many investigators who found that humic acid application better crop growth and productivity, and helped in more soil moisture retention (Celik et al., 2011). In case of the salicylic acid, application at the rate of 750 mg L^{-1} noted highest leaf area $plant^{-1}$ and LAI of maize crop. This might be due to salicylic acid which application enhanced the photosynthetic process which improved overall plant growth (El-Sabagh et al., 2017). Other possible reason is foliar application of salicylic acid at vegetative stage which increased photosynthetic efficiency (Leithy et al., 2015) resulting in maximum number of leaves and increased leaf area of maize and ultimately LAI. Foliar application of salicylic acid at the vegetative growth stage might reduce the leaf senescence, breakdown of chlorophylls, acceleration of chlorophyll regeneration and cell elongation and division (Synkova et al., 1997) which later helps in improved leaf area and LAI. Our findings are supported by the results of Rehman and Khalil (2016) who reported that leaf area of canola crop were higher with the foliar salicylic acid application.

Total dry matter production and partitioning is very important for the cause that it had an advanced correlation with crop growth rate, absolute growth rate, net assimilation rate, and water use efficiency (Amanullah et al., 2009). A significant difference in stem, leaves and ear dry weight of maize at silking and physiological maturity stage were noted with the use of humic acid and salicylic acid. Among the humic acid, highest stem, leaves and ear dry weight of maize at silking and physiological maturity were recorded when humic acid applied at the rate of 15 kg ha^{-1}. This might be due to humic acid which sustaining nutrients for a long period in the rhizosphere and then release gradually due to lengthy residue decomposition process which as a result improved dry weight at anthesis and maturity (Dev and Bhardwaj, 1995; Sharif et al., 2003). It may be due to the direct positive effect of humic acid on maize chlorophyll content, respiration acceleration, growth enzymes activation, increased penetration in plant cells (membranes) and indirectly through improved biological, physical and chemical conditions of soil (Rajpar et al., 2011). Humic acid makes enhancement in the soil physical and chemical properties and more dry matter production then causes hastening in biochemistry, physiology and productivity of plant (Canellas and Olivares, 2014). Humic acid causes an increase in the chlorophyll content of leaves which serves as a primary raw material for photosynthesis and promotes the growth and biomass production of crops (Mindari et al., 2014). Iqbal (2016) also reported maximum productivity in wheat crop, treated with humic acid as compared to control plots.

In case of the salicylic acid, maximum stem, leaves and ear dry weight of maize at silking and physiological maturity were recorded when salicylic acid applied at the rate of 15 kg ha^{-1}. This might be due to salicylic acid which maximum concentrations has been shown to enhanced biomass, reproductive yield in many plant species (Martel and Qaderi, 2016) and encourage the nitrogen assimilation (Nazar et al., 2011 and Ma et al., 2006). Salicylic acid has been found helpful in delaying senescence of leaves and flowers which reduces the premature loss of flowers and fruits, increased the number of photo synthetically active sites by which rate of photosynthesis is increased resulting into higher grain and biological yields. Salicylic acid not only involved in growth regulation and crop productivity but also affects many growth, biochemical and physiological traits of plants (Hayat et al., 2010).

V. CONCLUSION AND RECOMMENDATION

It is concluded from the experiment that application of humic acid at the rate of 15 kg ha^{-1} delayed phenology and improved dry matter partitioning of maize at silking and physiological maturity stage. Foliar application of salicylic acid at the rate of 750 mg L^{-1} delayed phenological parameters of maize crop and also proved better in dry matter partitioning. Therefore, it is recommended that the application of humic acid at the rate of 15 kg ha^{-1} and foliar salicylic acid application at the rate of 750 mg L^{-1} improved phenology and dry matter partitioning of maize at silking and physiological maturity stage in the agro-ecological conditions of Peshawar region.

REFERENCES

Amanullah, A. M., S. S. Malhi, and R. A. Khattak. 2009. Effects of P-fertilizer source and plant density on growth and yield of maize in Northwestern Pakistan. J. Plant Nutri. 32: 2080–93. doi:10.1080/01904160903308168.

Arfan, M., H.R. Athar and M. Ashraf. 2007. Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in differently adapted spring wheat cultivars under salt stress? J. Plant Physiol. 6: 685-694.

Arif, Y., F. Sami, H. Siddiqui, A. Bajguz and S. Hayat. 2020. Salicylic acid in relation to other phytohormones in plant: A study towards physiology and signal transduction under challenging environment. Environ. Exper. Bot. 175: 104040.

Atiyeh, R.M., Lee, S., Edwards, C.A., Arancon, N.Q. and Metzger, J.D., 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. Bioresource Tech. 84(1): 7-14.

Canellas, L.P. and Olivares, F.L., 2014. Physiological responses to humic substances as plant growth promoter. Chemical and Biological Technologies in Agriculture, 1(1): 3.

Celik, H., Katkat, A.V., Aşık, B.B. and Turan, M.A., 2011. Effect of foliar-applied humic acid to dry weight and mineral nutrient uptake of maize under calcareous soil conditions. Commu. Soil Sci. Plant Anal. 42(1): 29-38.

Cui, H., E. Gobbato, B. Kracher, J. Qiu, J. Bautor and J. E. Parker. 2017. A core function of EDS1 with PAD4 is to protect the salicylic acid defense sector in Arabidopsis immunity. New Phytol. 213: 1802–1817.

Dantas, R. S., S. C. Alberto and J. G. M. M. Henrique. 2018. Wheat nutrition and growth as affected by humic acid-phosphate interaction. J. Plant Nutr. Soil Sci. 181: 870–877.

Dev, S.P. and Bhardwaj, K.K.R., 1995. Effect of crop wastes and nitrogen levels on biomass production and nitrogen uptake in wheat-maize sequence. Annals Agric. Res. 16: 264-267.

Ei-Mergawi R. A., and El-Wahed. 2020. Effect of exogenous salicylic acid or indole acetic acid on their endogenous levels, germination and growth in maize. Bull. Nat. Research. Centre. 44: 1-8.

El-Sabagh, A., K, A.A. Abdelaal and C. Barutcular. 2017. Impact of antioxidants supplementation on growth, yield and quality traits of canola (Brassica napus L.) under irrigation intervals in north Nile delta of Egypt. J. Exp. Biol. Agric. Sci. 5(2): 163-172.

Fariduddin, Q., S. Hayat and A. Ahmad. 2003. Salicylic acid influences net photosynthetic rate, carboxylation, efficiency of nitrate reductase activity and seed in Brassica juncea L. Photosynthetica, 41: 281-284.

Farooq, M., T. Aziz, M. Hussain, H. Rehman., K. Jabran and M.B. Khan. 2008. Glycinebetaine improve the chilling tolerance in hybrid maize. J. Agron. Crop Sci. 194: 152-160.

Figliolia, A., Benedetti, A., Izza, C., Indiati, R., Rea, E., Alianiello, F., Canali, S., Biondi, F.A., Pierandrei, F. and Moretti, R., 1994. Effects of fertilization with humic acids on soil and plant metabolism: a multidisciplinary approach. Note I: crop production: 579-584.

Hayat, Q., S. Hayat, M. Irfan and A. Ahmad. 2010 effect of exogenous salicylic acid under changing environment. J. Exp. Bot. 68: 14-25.

Iqbal, A., Amanullah and M. Iqbal. 2015. Impact of potassium rates and their application time on dry matter partitioning, biomass and harvest index of maize (Zea mays) with and without cattle dung application. Emir. J. Food Agric. 27: 447–453.

Iqbal, B., S. Anwar, F. Iqbal, W.A. Khattak, M. Islam and S. Khan. 2016. Response of wheat crop to humic acid and nitrogen levels. EC Agric. 3(1): 558-565.

Khaled, H. and Fawy, H.A., 2011. Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. Soil Water Res. 6(1): 21-29.

Khan, M.I. and Jan, A., 2017. Maize response to soil conditioning and irrigation regimes. Int. J. Biosci. 11(6): 100-115.

Khan, M.Z., M.E. Akhtar, S. Ahmad, A. Khan and R.U. Khan. 2014. Chemical composition of lignitic humic acid and evaluating its positive impacts on nutrient uptake, growth and yield of maize. Pak. J. Chem. 4(1): 19-25.

Klessig, D. F., H. W. Choi and D. A. Dempsey. 2018. Systemic acquired resistance and salicylic acid: Past, present, and future. Mol. Plant-Microbe Interact. 31: 871–888.

Krantev, A., R.Yordanova and L. Popova. 2006. Salicylic acid decreases Cd toxicity in maize plants. Gen. Appl. Plant Physio. Special issue: 45-52.

Leithy, S.M., B.A. Leila, E.F. Abdallah and M.S. Gaballah. 2015. Response of canola plants to antitranspirant levels and limited Irrigation. American-Eurasian J. Sustainable Agric. 9 (4): 83-87.

Ma, J. K., Y. Z. Yuan, J. Q. Ou, M. Ou-Yang, S.Y. Bao and C. F. Zhang. 2006. Relieving effect of exogenous salicylic acid on rice (Oryza sativa L.) seedling roots under NaCl stress. J. Wuhan Univ. (Nat. Sci. Ed.). 52 (4): 471-474.

Martel, A.B. and M.M. Qaderi. 2016. Does salicylic acid mitigate the adverse effects of temperature and ultraviolet B radiation on pea (Pisum sativum) plants? Environ. Exp. Bot. 122 (Supplement C): 39-48.

Metraux, J.P. 2001. Systematic acquired resistance and salicylic acid: current state of knowledge. Eurp. J. Plant Path. 13-18.

Mindari, W., Aini, N., Kusuma, Z. and Syekhfani, S., 2014. Effects of humic acid-based cation buffer on chemical characteristics of saline soil and growth of maize. J. Deg. Mining Lands Manag. 2(1): 259-268.

Nazar, R., N. Iqbal, S. Syeed and N.A. Khan. 2011. Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulfur assimilation and antioxidant metabolism differentially in two mungbean cultivars. J. Plant Physiol. 168(8): 807-15.

Pakistan Economic Survey. 2020-2021. Finance and economic affairs division, ministry of finance, Govt. of Pakistan, Islamabad.

Puglisi, E., Fragoulis, G., Ricciuti, P., Cappa, F., Spaccini, R., Piccolo, A., Trevisan, M. and Crecchio, C., 2009. Effect of a humic acid and its size-fractions on the bacterial community of soil rhizosphere under maize (Zea mays L.). Chemosphere, 77(6): 829-837.

Purwanto, B.H., P. Wulandari, E. Sulistyaningsih, S.N.H. Utami and S. Handayani. 2021. Improved corn yields when humic acid extracted from composted manure is applied to acid soils with phosphorus fertilizer. Appl. Environ. Soil Sci. https://doi.org/10.1155/2021/8838420

Rajpar, I., Bhatti, M.B., Zia-ul-Hassan, Shah, A.N. and Tunio, S.D., 2011. Humic acid improves growth, yield and oil content of Brassica compestris L. Pak. J. Agri. Agric. Eng. Vet. Sci. 27(2): 125-133.

Rehman, A. and S.K. Khalil. 2018. Effect of exogenous application of salicylic acid, potassium nitrate and methanol on canola growth and phenology under different moisture regimes. Sarhad J. Agri. 34(4): 781-789.

Rosa, S. D., C. A. Silva and H. Maluf. 2018. Wheat nutrition and growth as affected by humic acid-phosphate interaction. J. Plant Nutr. Soil Sci. 181: 870–877.

Santa Bahadur, B.K. and Shrestha, J., 2014. Effect of conservation agriculture on growth and productivity of maize (Zea mays L.) in Terai region of Nepal. World J. Agric. Res. 2(4): 168-175.

Shafi, M. I., M. Adnan, S. Fahad, F. Wahid, A. Khan and Z. Yue. 2020. Application of single superphosphate with humic acid improves the growth, yield and phosphorus uptake of wheat (Triticum aestivum L.) in Calcareous Soil. Agronomy, 10:12-24.

Sharif, M., Khattak, R.A. and Sarir, M.S., 2003. Residual effect of humic acid and chemical fertilizers on maize yield and nutrient accumulation. Sarhad J. Agric. 19(4): 543-550.

Sharif, M., R.A. Khattak and M.S Sarir, 2002. Effect of different levels of lignitic coal derived humic acid on growth of maize plants. Commun. Soil Sci. Plants Anal. 33(19-20): 3567-3580.

Shi, Q., Z. Bao, Z. Zhu, Q. Ying and Q. Qian. 2006. Effect of different treatments of sailylic acid on heat tolerance, chlorophyll fluorescence and antioxidant enzyme activity in seedling of Cucumis sativa L. Plant Growth Regul. 48: 127-135.

Sibgha, N., H.R. Attar and M. Ashraf. 2013. Interactive effects of watering regimes and exogenously applied osmoprotectants on earliness indices and leaf area index in cotton (Gossypium hirsutum L.) Crop Pak. J. Bot. 45(6): 1873-1881.

Steel, R.G.D. and J.H. Terrie. 1996. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw-Hill, New York.

Susic, M. (2016). Replenishing humic acids in agricultural soils. Agronomy, 6(4), 45.

Synkova, H., N. Wilhelmova, Z. Sestak and J. Pospislova, 1997. Photosynthesis in transgenic plants with elevated cytokinin contents. In: Pessarakli, M. (ed.), Handbook of Photosynthesis. Marcel Deckker. New York.

Tan, K.H., 2003. Humic Matter in Soil and Environment, Principles and Controversies. CRC Press.

Turkmen, Ö., Dursun, A., Turan, M. and Erdinc, C., 2004. Calcium and humic acid affect seed germination, growth, and nutrient content of tomato (Lycopersicon esculentum L.) seedlings under saline soil conditions. Acta Agriculturae Scandinavica, 54(3): 168-174.

Ullah, C., C. J. Tsai, S. B. Unsicker, L. Xue, M. Reichelt, J. Gershenzon and A. Hammerbacher. 2019. Salicylic acid activates poplar defense against the biotrophic rust fungus Melampsora larici-populina via increased biosynthesis of catechin and proanthocyanidins. New Phytologist, 221(2): 960-975.

Xu, J. C., E. Mohamed, Q. Li, T. Lu, H. J. Yu and W. J. Jiang. 2021. Effect of humic acid addition on buffering capacity and nutrient storage capacity of soilless substrates. Front. Plant Sci. 12: 749

Zhang, S. Q., Y. U. A. N. Liang, L. I. Wei, Z. A. Lin, Y. T. LI, S. W. HU and B. Q. ZHAO. 2019. Effects of urea enhanced with different weathered coal-derived humic acid components on maize yield and fate of fertilizer nitrogen. J. Integrative Agri., 18(3): 656-666.

Zhu, J. and H. Peng. 2021. Ammonia volatilization loss and emission reduction measures in paddy fields. J. Agro-Enviro. Sci., 40(1):16-25.

Authors

First Author – Sufyan Hameed, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: sufyanhameed94@gmail.com

Second Author – Shazma Anwar, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: anwar.shazma@gmail.com

Third Author – Shahen Shah, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: shahenshah@aup.edu.pk

Fourth Author – Faiq Ahmad, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: faiqriaz@gmail.com

Fifth Author – Maaz Khan, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: khanmaaz820@gmail.com

Sixth Author – Sayed Zubair, Department of Horticulture, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: sayedzubair.aup@gmail.com

Seventh Author – Muzammil Aziz, Department of Horticulture, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: muzammilaziz.uap@gmail.com

Correspondence Author – Shazma Anwar, Department of Agronomy, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and Email: anwar.shazma@gmail.com