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Akash
Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Mohit Naik
Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Deepak Kumar
Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Anaytullah Siddique
Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Corresponding Author:
Anaytullah Siddique
Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar, Punjab, India

Priming mediated morphological changes in growth and yield of sorghum cultivars (*Sorghum bicolor* L.)

Akash, Mohit Naik, Deepak Kumar and Anaytullah Siddique

Abstract
An experiment was planned and executed over the Research Farm of LPU, to understand the impact of seed priming with Mg $(NO_3)_2$ on morphological changes and the yield of sorghum cultivars. The varietal response showed that V_2 (Dairy Green) performed well for most of the morphological and yield parameters such as plant height, fresh and dry weight, number of leaves, leaf area, LAI, SPAD readings and biological yield (235.7 cm, 345.7 g, 85.4 g, 9.2, 1555.2 cm^2 $plant^{-1}$, 7.1, 5.2, 37.8, 30.5, 341.58) while V_3 (Shri Ram Green) was recorded better for the economic yield and HI% as compared to rest of the varieties (Fat boy and Dairy green). However, among the concentrations of seed priming treatment, C_2 (7.5 mM) was recorded better for all the morphological as we as yield of sorghum (229.9 cm, 319.2 g, 79.4 g, 9.4, 1535.0 cm^2 $plant^{-1}$, 7.3, 5.1, 38.2, 31.0, 341.11) as compared to rest of the concentrations of the priming treatments C_1 and C_3 (5.5mM and 9.5 mM) including control C_0 (Non primed seed). Results of statistics at ($P>0.05$) showed that most of the parameters were recorded as significant while the interaction of VXC showed a non-significant difference for the parameters such as the number of leaves, leaf area, and LAI at harvest and SPAD at 60 DAS.

Keywords: HI, Mg $(NO_3)_2$, Seed priming, SPAD reading and sorghum crop

Introduction
Sorghum (*Sorghum bicolor* L.) also known as Indian millet, is one of the major cereal crops in India that belongs to the Poaceae family. As the leading country in the production of sorghum is a concern, India is the second-largest producer in the world. Sorghum is 5^{th} in the world among the cereal crops after wheat, rice, corn and barley (Ananda *et al.*, 2020 and Kangama, 2017) [1, 8]. It requires less irrigation and fertilizer as compared to the other cereals like wheat and rice. So it is also more suitable for the areas where not many good climatic conditions and irrigation are provided (Hossain *et al.*, 2022 and Fatima *et al.*, 2020) [7, 4]. In semi-arid regions of India and Africa sorghum and other grains are contributing to overall calorie intake. To reach the proper food supply for cattle and industrial applications it is preferred to be grown in semi-arid regions for fodder (Mundia *et al.*, 2019 and Singh *et al.*, 2019) [11, 17]. It has different varieties for different purposes such as grain sorghum, fodder sorghum and groom sorghum used for grains, fodder and brushes. Its grains are rich in starch while the stem and leaves are naturally coated with wax which helps in the survival of the plant under extremely low availability of water (Hadebe *et al.*, 2017) [5]. Sorghum crop is also getting attention as a bio-energy crop as a result of a renewed national and international focus on sustainable bio-energy for a variety of reasons. Moreover, sorghum crop residues and green plants are also used as sources of animal feed, building material and cooking fuel particularly in arid terrain locations (Rao *et al.*, 2019 and Velmurugan *et al.*, 2020) [12, 18]. Priming with nitrate salts such as $Mg(NO_3)_2$ is one of the most effective chemicals for improving all phases of plant growth, particularly the beginning stage, as well as overcoming the effects of temperature, heat, salinity, and drought stress (Siddique and Bose, 2015) [15]. Seed priming is a pre-germination procedure that entails allowing the seed to absorb water before drying it off to start the preliminary event of germination right up to the point of radical emergence but avoid radical protrusion (Arun *et al.*, 2017) [2]. There have been a lot of studies on seed priming and the findings of studies clearly show how necessary priming is to get a good crop yield in many tropical crops like rice, maize, sorghum, and pigeon pea (Rhaman *et al.*, 2020 and Singh *et al.*, 2015) [14, 16].

Materials and Methods
The present piece of work was planned and executed over the Agricultural Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab in 2021-22 in the *Rabi* season.

The experimental varieties for this study were collected from the registered private shop of Jalandhar. The experiment was carried out in FRBD along with three cultivars namely (Fat boy, Dairy Green and Shri Ram Green) along with three concentrations of priming agent Mg $(NO_3)_2$ such as (5.5, 7.5, 9.5 mM) represented as a C_1, C_2 and C_3 while three replications were considered to reduce the error. Before the seed priming, the proper disinfection process of healthy and bold seeds was followed by placing in 0.1% $HgCl_2$ solution for two minutes followed by the cleaning of the seed with distilled water. Seeds were soaked for 12 hours in respective solutions and dried back up to their original weight under the fan. A standard package of practices and intercultural operations were followed to complete the research work. The full dose of P and K was given to the crop at the time of sowing by single super phosphate and MOP while nitrogen was supplied in two equal half. Standard norms were also followed to record the morphological and yield-related parameters while to understand the greenness level in the plant, SPAD-502 was used. The following formulas were used to calculate the LAI and HI%.

$$\text{LAI} = \frac{\text{Total leaf area of plant (cm)}}{\text{Ground area (cm)}}$$

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Seed Yield)}}{\text{Biological Yield}} \times 100$$

The analysis of variance shows that all the parameters were statistical significance at $p < 0.5\%$. The posthoc analysis of the same parameters was also carried out and found that varieties and priming treatments were significant while interaction studies were found non-significant for some of the parameters such as the number of leaves, leaf area, and LAI at harvest and SPAD reading at 60 DAS.

Results and Discussion

Data presented in (table- 1) reveals the impact of seed priming treatment with Mg $(NO_3)_2$ on plant height (cm), fresh and dry weight (g), number of leaves and leaf area (cm^2) in sorghum cultivars. It was observed from the mean data of varietal response in all the parameters, variety V_2 (Dairy green) performed well as compared to V_1 and V_3 which was Fat boy and Shri Ram Green recorded 235.7, 345.7 and 85.4, 9.2 and 1555.2 for the respective parameters such as plant height (cm), fresh and dry weight (g), number of leaves and leaf area (cm^2). Similarly, mean data of priming treatment showed that C_2 (7.5 mM) performed well and recorded 229.9 cm, 319.2 g and 79.4 g $plant^{-1}$, 9.4 and 1535.0 cm^2 $plant^{-1}$ for the same parameters mentioned above as compared to rest of the treatments (C_1 and C_3) including control. Interaction studies among the V X C showed that V_1 and V_2 performed well in combination with C_2 for the plant height, fresh and dry weight parameters while in the case of V_3, the initial three parameters such as plant height, fresh and dry weight were recorded maximum in V_3C_3 while resting of the parameters such as the number of leaf and leaf area were recorded highest in the V_3C_2 (table-1). Data presented in (table- 2) showed the impact of seed priming treatment with Mg $(NO_3)_2$ on leaf area index and SPAD readings of two intervals such as 60 DAS and at harvest stage sorghum cultivars. It was observed from the mean data of varietal response showed that in all the parameters, variety V_2 performed well as compared to the rest of the varieties such as V_1 and V_3 which were recorded at 7.1, 5.2 and 37.8, 30.5 for the respective parameters like leaf area index and SPAD reading at 60 DAS and at harvest. Similarly, mean data of priming treatment showed that C_2 performed well i.e. 7.3, 5.1 and 38.2, 31.0 for the same parameters mentioned above as compared to the rest of the treatments i.e. C_1 and C_3 including control. Interaction studies among the V X C showed that C_2 performed well along with all varieties as compared to the rest of the interactions except for V_3 at harvest. Data presented in (fig-1) reveals the impact of seed priming treatment with Mg $(NO_3)_2$ on biological yields, economical yield g $plant^{-1}$ and harvest index % at harvest stage in sorghum cultivars. It was observed from the mean data of varietal response showed that variety V_3 also performed well for the economic yield and HI% which was 69.75 g $plant^{-1}$ and 25.16 while the biological yield was recorded maximum V_3 as compared to rest of the varieties. Similarly, mean data of priming treatment showed that C_2 performed well 341.11, 67.89 g $plant^{-1}$ and 20.22% for the biological yield, economical yield and harvest index respectively. Interaction studies among the V X C showed that all three varieties performed well in combination with C_2 but V_3C_2 was one of the bets in comparison with other combinations of the treatments for all parameters presented in (fig-1).

Discussion

Sorghum is one of the most important dual-purpose crops because the grains of this crop is utilized by human beings as well as a fodder crop for animals. Morphological growth of the sorghum plant was recorded best in V_2 in comparison to V_1 and V_3 while among the priming chemicals, C_2 was recorded best for the same morphological parameters. However, interaction studies indicated that the V_1 and V_2 were performing well with C_2 but V_3 was showing best with C_3 for most morphological and yield attributes (Mokhtari and Kizilgeci, 2021; Rezai et al., 2017 and Komal and Siddique, 2020) [10, 13, 9]. SPAD reading is a representative of chlorophyll while its maximum reading indicates the positive response of seed priming treatment on morphological growth such as PH, fresh and dry weight of the plant, number of leaves, leaf area, LAI, HI% and grain yield which showed that rate of photosynthesis and portioning of photosynthate from the source to sink was adequate which helped in the vigorous growth of sorghum plant (Komal and Siddique, 2020 and Zhang *et al.*, 2015) [9]. The increase in SAPD reading may be due to the priming agent Mg $(NO_3)_2$ hence the synthesis of chlorophyll in the plant because Mg is required as a central atom in them (Hawkesford *et al.* 2012 and Chen *et al.* 2018) [6, 3].

Table 1: Effect of seed priming with Mg $(NO_3)_2$ on plant height (cm), fresh and dry weight (g), number of leaves and leaf area (cm^2) at harvesting stage in sorghum crop

Treatment details		Plant height (cm)	Fresh weight (g)	Dry weight (g)	No. of Leaves	Leaf Area (cm^2)
V_1	C_0	203.8±6.9	278.7±8.1	69.7±2.0	6.7±0.8	1345.3±58.4
	C_1	222.1±4.0 [8.25]	285.3±5.0 [2.34]	71.6±0.8 [2.16]	7.0±0.5 [4.76]	1481.7±69.0 [9.22]

	C_2	241.8±2.7 [15.72]	328.3±10.4 [15.13]	82.4±3.1 [15.36]	8.7±0.3 [23.08]	1587.7±88.3 [15.27]
	C_3	232.1±6.8 [12.19]	306.3±29.2 [9.03]	76.7±7.6 [9.14]	7.3±0.8 [9.09]	1514.3±41.6 [11.17]
V_2	C_0	219.7±6.4	337.66±6.81	82.9±2.3	7.7±0.3	1441.7±35.2
	C_1	231.10±4.6 [4.95]	338.0±7.2 [0.10]	83.5±1.8 [0.74]	8.5±0.5 [9.80]	1550.3±49.7 [7.03]
	C_2	252.9±1.1 [13.14]	363.3±25.2 [7.06]	89.2±3.8 [7.05]	10.7±0.6 [28.13]	1618.7±33.2 [10.92]
	C_3	239.0±5.3 [8.09]	343.7±6.3 [1.75]	86.0±1.5 [3.64]	10.0±1.0 [23.33]	1610.3±29.9 [10.48]
V_3	C_0	184.6±5.1	213.3±15.3	53.6±3.5	6.0±1.0	1215.0±63.2
	C_1	192.8±3.4 [4.25]	261.7±4.7 [18.47]	65.5±1.1 [18.23]	6.8±1.0 [12.20]	1309.3±13.6 [7.22]
	C_2	195.0±2.3 [5.30]	266.0±5.3 [19.80]	66.8±1.5 [19.72]	8.8±2.2 [32.08]	1398.7±27.1 [13.14]
	C_3	198.3±3.5 [6.88]	279.7±10.0 [23.72]	69.9±2.5 [23.34]	7.5±1.3 [20.00]	1295.3±25.4 [6.23]
Mean Table						
V_1		224.9^{b}	299.7^{b}	75.1^{b}	7.4^{b}	1482.2^{b}
V_2		235.7^{c}	345.7^{c}	85.4^{c}	9.2^{c}	1555.2^{c}
V_3		192.7^{a}	255.2^{a}	64.0^{a}	7.3^{a}	1304.6^{a}
C_0		202.7^{a}	276.6^{a}	68.7^{a}	6.8^{a}	1334.0^{a}
C_1		215.4^{b}	295.0^{b}	73.6^{b}	7.4^{b}	1447.1^{b}
C_2		229.9^{d}	319.2^{d}	79.4^{d}	9.4^{d}	1535.0^{d}
C_3		223.1^{c}	309.9^{c}	77.6^{c}	8.3^{c}	1473.3^{c}

CD at 5%	CD	SE(m)	CD	SE(m)	CD	SE(m)	CD	SE(m)	CD	SE(m)
V	3.7	1.3	11.6	3.9	2.7	0.9	0.8	0.3	42.2	14.3
C	4.3	1.5	13.4	4.5	3.1	1.0	0.9	0.3	48.7	16.5
VXC	7.5	2.5	23.1	7.8	5.4	1.8	NS	0.5	NS	28.6

Table 2: Effect of seed priming with Mg $(NO_3)_2$ on Leaf area index and SPAD readings at 60 DAS and harvesting stage in sorghum crop

Treatment details		LAI		SPAD readings	
		60 DAS	At harvest	60 DAS	At harvest
V_1	C_0	5.4±0.0	4.5±0.2	33.9±1.2	27.7±1.1
	C_1	6.6±0.1 [18.27]	4.9±0.2 [9.22]	37.6±6.2 [9.78]	29.1±1.4 [5.00]
	C_2	7.6±0.2 [28.45]	5.3±0.3 [15.27]	40.6±0.7 [16.33]	32.7±0.5 [15.37]
	C_3	7.0±0.3 [22.46]	5.0±0.1 [11.17]	35.8±2.9 [5.07]	27.7±1.3 [0.00]
V_2	C_0	6.4±0.1	4.8±0.1	34.6±1.7	28.1±1.9
	C_1	6.9±0.7 [8.27]	5.2±0.2 [7.03]	37.6±1.6 [10.36]	30.9±2.0 [9.08]
	C_2	7.9±0.2 [19.46]	5.4±0.1 [10.92]	41.5±2.1 [16.67]	32.8±1.3 [14.20]
	C_3	7.0±0.6 [9.82]	5.4±0.1 [10.48]	36.4±2.1 [4.99]	30.0±1.6 [6.43]
V_3	C_0	5.6±0.2	4.0±0.2	27.2±2.2	21.3±0.7
	C_1	5.8±0.0 [1.95]	4.4±0.4 [7.22]	28.5±2.3 [4.53]	32.6±1.0 [34.73]
	C_2	6.5±0.0 [13.50]	4.7±0.1 [13.14]	32.5±1.7 [16.33]	27.3±2.5 [22.22]
	C_3	6.3±0.0 [10.34]	4.3±0.9 [6.23]	32.0±2.0 [14.80]	25.0±1.7 [14.86]
Mean Table					
V_1		6.7^{b}	4.9^{b}	37.0^{b}	29.3^{b}
V_2		7.1^{c}	5.2^{c}	37.8^{c}	30.5^{c}
V_3		6.0^{a}	4.3^{a}	30.1^{a}	26.5^{a}
C_0		5.8^{a}	4.4^{a}	31.9^{a}	25.7^{a}
C_1		6.4^{b}	4.8^{b}	34.9^{c}	30.9^{c}
C_2		7.3^{d}	5.1^{d}	38.2^{d}	31.0^{d}
C_3		6.8^{c}	4.9^{c}	34.7^{b}	27.6^{b}

CD at 5%	CD	SE(m)	CD	SE(m)	CD	SE(m)	CD	SE(m)
V	0.2	0.1	0.1	0.0	2.3	0.8	1.3	0.4
C	0.3	0.1	0.2	0.0	2.6	0.9	1.5	0.5
VXC	0.5	0.2	NS	0.09	NS	1.54	2.7	0.9

Note: V_1= Fat boy, V_2= Dairy green, V_3= Shriram green and C0= Control, C_1= 5.5 mM C_2= 7.5 mM C_3= 9.5 mM

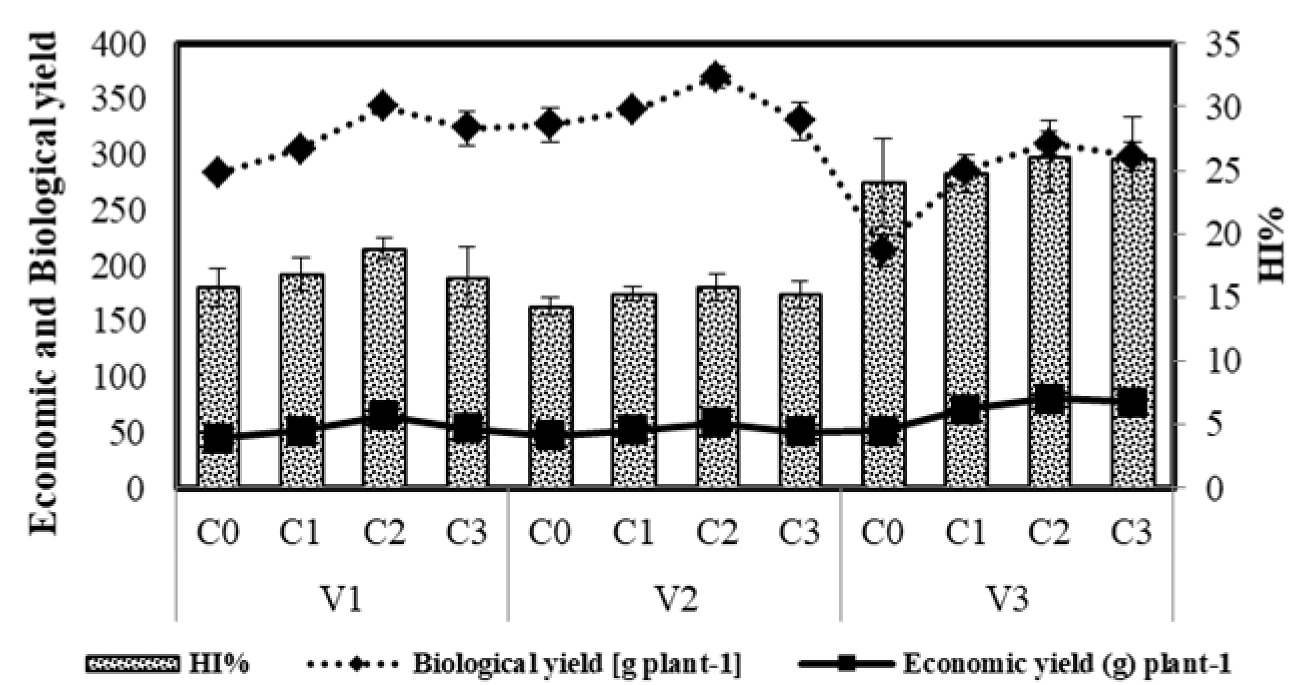

Fig 1: Effect of seed priming with Mg (NO3)2 on economic yield, biological yield and HI% of sorghum varieties

Conclusion

Sorghum is one of the most important dual crops which we use mostly as grain or as a fodder crop. In both cases, seed priming with magnesium was found best to enhance the biomass as well as grain. In the present piece of work, we found that SPAD reading was increased drastically in the treated set as compared to the nontreated set consequently the morphological growth and yield were found better because the rate of photosynthesis played a crucial role due to the increase of SPAD reading which represent the chlorophyll in the plant.

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