Effect of Salicylic acid spray and molybdenum priming on yield and physiological properties of mungbean

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Abstract-

An experiment was carried out at the Agronomy Research Farm, The University of Agriculture, Peshawar during summer season 2019 to study the effect of molybdenum seed priming (un-primed, water primed, 93 186 and 279 mg M0 L^{-1}) and salicylic acid foliar spray (0, 100, 200 and 300 mg L^{-1}) on yield of mungbean. Randomized complete block design was used consisted of three replications. Sodium molybdate was used as source of molybdenum seed priming while salicylic acid foliar sprays were used after one month of sowing. Findings of the experiment depicted that seed priming with molybdenum @ 279 mg L^{-1} significantly enhanced nodules $plant^{-1}$ (24), seed yield (783 kg ha^{-1}), soil N content (0.073%) and grain N content (3.5%). Higher 1000 grains weight (35 g), HI (25%) and proline content (0.670 µg g^{-1} frsh weight). Salicylic acid foliar spray @ of 200 mg L^{-1} significantly improved biological yield (2852 kg ha^{-1}) and grain yield (726 kg ha^{-1}). Maximum nodules $plant^{-1}$ (20), 1000 grains weight (35.3 g), soil N content (0.068%) and seed N content (3.0%) were sustained by plants sprayed at the rate of 200 mg L^{-1} of salicylic acid and statistically similar to foliar application of salicylic acid @ of 300 mg L^{-1}. Maximum H_2O_2 (0.896 nmol g^{-1} fresh weight) was reported with molybdenum applied @ of 93 mg L^{-1} and salicylic acid spray @100 mg L^{-1} depicted maximum (1.03 nmol g^{-1} fresh weight) H_2O_2. Harvest index (25%) was recorded at the rate of 300 mg L^{-1} salicylic acid foliar application. It is concluded that mungbean seeds priming with molybdenum @ 279 mg L^{-1} and salicylic acid foliar application @ 200 mg L^{-1} attained maximum seed yield and therefore recommended for the studied area.

Index Terms- Salicylic acid, Molybdenum, Proline content, Hydrogen peroxide and crude protein

I. INTRODUCTION

Mungbean (Vigna radiata L.) generally known as green gram, is a short-season leguminous crop with a wide range of adaptability, little need for input, and the potential to improve soil through atmospheric nitrogen fixation [48]. Mungbean can be used as green manure, food, or feed [67]. In Pakistan, mungbean is a famous kharif crop and one of the most well-known conventional crops [49]. Mungbean is cultivated in Pakistan on 162,500 ha, producing 122,000 tonnes, and on 6,900 ha in KP, producing 4,5000 tonnes [57].

The availability and uptake of macro and micronutrients from the soil are essential to plants' nutrition, and their imbalanced application reduces crop production. Through biological nitrogen fixation and its effect on plant growth, micronutrients play a crucial role in the increased production of legumes. Molybdenum, a crucial element for plant growth, is present in soil in minute amounts (Golezani et al., 2019). Rhizobium needs molybdenum to promote nitrogen fixation, and it also causes nodules to develop [13]. The nitrate reductase and nitrogenase enzymes require molybdenum to function, and it also makes up the nitrogenase enzyme. Molybdenum is required by Rhizobium for the fixation process [37]. The amount of molybdenum that is available for plant growth is influenced by soil drainage, organic matter in soil colloids, and soil pH [39].

In south Asia's cereal-based system (12 million acres), there is a severe lack of soil micronutrients [60]. In diets based on legumes, molybdenum has a low level of bioavailability [38]. In order to improve growth and micronutrient status in plants, animals, and people, a low-cost technology is needed to integrate micronutrients into plant systems. This deficiency can be solved through nutrient seed priming [35]. Nutrient seed priming involves pre-treating seeds in a solution that contains the necessary nutrients rather than just soaking them in water [9]. As a result, micronutrient deficiencies can be completely eliminated, and a variety of cereals and legumes can produce larger yields and seedlings [25].

Drought stress is the primary environmental element that severely impacted the growth and production of many field crops in the context of a climate change scenario. When compared to other growth stages, the reproductive phase is more severely affected by drought stress, which significantly lowers mungbean yield [66]. Natural plant hormone salicylic acid (2-hydroxybenzoic acid) is essential for allowing plants to withstand a variety of environmental challenges, including heat, drought, and salt tolerance [18]. It is a micro plant nutrient that plays a crucial role in photosynthesis, ion transport, transpiration, and other processes essential to the growth and development of plants [27].

When the seeds were pretreated with salicylic acid prior to sowing, mungbean seedling development and germination were improved [19]. In the relatively recent and well-known practise of "foliar fertilization," liquid nutrients are sprayed directly into the leaves of plants [10]. Plants with foliar fertilizer can be a useful addition to soil fertilization. Elemental foliar application has been discovered to be more efficient than soil application [40]. Nutrition given to the foliar layer is absorbed by the epidermal cells, stomata, leaf hairs, and cuticular cracks [72]. Salicylic acid foliar application enhanced many physiological and biochemical characteristics of mungbean plant by speeding up absorption, leading to greater chlorophyll concentration and hill response in the leaves [54].

Legumes high production is ensured by micronutrients. One of them, molybdenum, has the ability to speed up the rhizobium's nitrogen fixation process. Growing climate change had a negative impact on both the quantity and quality of crops. It appears that plants' ability to withstand its harmful effects depends on salicylic acid. Increasing importance of molybdenum and salicylic acid in increasing mungbean productivity, the aim of this study is to evaluate the optimal level of molybdenum seed priming and salicylic acid foliar spray for enhancing mungbean seed yield.

Identify the constructs of a Journal – Essentially a journal consists of five major sections. The number of pages may vary depending upon the topic of research work but generally comprises up to 5 to 7 pages. These are:

1) Abstract
2) Introduction
3) Research Elaborations
4) Results or Finding
5) Conclusions

In Introduction you can mention the introduction about your research.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

It's the foremost preliminary step for proceeding with any research work writing. While doing this go through a complete thought process of your Journal subject and research for it's viability by following means:

1) Read already published work in the same field.

2) Goggling on the topic of your research work.
3) Attend conferences, workshops and symposiums on the same fields or on related counterparts.
4) Understand the scientific terms and jargon related to your research work.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

IV. MATERIALS AND METHODS

Response of mungbean to molybdenum seed priming and salicylic acid foliar spray was assessed at Agronomy Research Farm, The University of Agriculture, Peshawar during summer season 2019. Randomized complete block design was used having three replications. Plot size was 3 m x 2.4 m having six rows. Row to row distance was 40 cm and plant to plant distance was 10 cm. The experiment was consisted of five Mo seed priming levels (unprimed, water primed, 93, 186, and 279 mg Mo L^{-1}) and four salicylic acid foliar sprays (0, 100, 200, and 300 mg L^{-1}). The mungbean variety Ramzan-92 was sown @ 25 kg ha^{-l}. Nitrogen was applied as a starter dose @ of 25 kg ha^{-1} at the time of sowing. First irrigation was applied 20 DAS and 2nd irrigation was given at the time of flowering and 3rd irrigation was given at the time of pod formation. After 25 days of seeding, the crop was thinned. First weeding was done 25 DAS and 2nd prior the reproductive stage to keep the crop free of weeds.

Priming procedure

Sodium molybdate (Na2MoO4), which was used for seed priming, was converted into molybdenum. The molar mass of sodium molybdate, which contains 95.94 g of molybdenum, is 205.918 g mol^{-1}. Sodium molybdate solutions of 0.2 g L^{-l}, 0.4 g L^{-l}, and 0.6 g L^{-l} were created for 93 mg Mo L^{-1}, 186 mg Mo L^{-1}, and 279 mg Mo L^{-1}, respectively. The sodium molybdate solution was used to soak 288 g of mungbean seeds for six hours, followed by 30 minutes of shade drying. Mungbean grains were immersed in water for six hours during the water priming treatment and then dried in the shade for 30 minutes during the unprimed treatment.

Procedure for salicylic acid foliar application

For the SA spray application, the water needed $plot^{-1}$ was computed using a water sprayer, and after spraying different concentrations of salicylic acid (100 mg/L, 200 mg/L, and 300 mg/L), the amount of solution needed $plot^{-1}$ was calculated. Since water only partially dissolves salicylic acid, a solution of one liter of distilled water and 20 mL of ethanol was made and stirred with a magnetic stirrer for two minutes at room temperature. One month after sowing of mungbean crop, each salicylic acid sample was put into a one-liter container with a sprayer nozzle and applied to the relevant plots.

Number of nodules $plant^{-l}$

The number of nodules on five randomly selected plants from each plot were counted and averaged prior to flower initiation.

Thousands seed weight (g)

Thousands seeds were counted through seed counter from the seed lot of each experimental plot weighed and averaged.

Biological yield (kg ha^{-l})

The four central rows of each experimental plot were harvested by hand with the help of sickle bundled and sundried for ten days in the field. To calculate the biological yield, each bundle was individually weighed on a scale in the field. The data were then changed to kg ha^{-l}.

Seed yield (kg ha^{-l})

Each experimental plot four central rows were harvested with a sickle. The samples were sun dried, threshing, and seed weighing using an electronic scale. The data was then changed to kg ha^{-l}.

Harvest index (%)

The harvest index was calculated by dividing each experimental plot grain yield by biological yield, then multiplying by 100.

Soil N content (%)

The total amount of N in the soil was calculated using the Kjeldahl method [15]. Soil sample of 0.5g was digested in the presence of a digesting solution that contained 3 mL of pure H_2SO_4. The samples were heated to 350 °C until they turned a light green colour after being first digested at 50 °C. After the samples were cooled, they were diluted, and 20 ml of the diluted digestion was then distilled with a 40 percent NaOH solution and a mixed indicator of boric acid. Another computation was performed after accounting for blank readings and titrating the outcome against HCl solutions.

Seed N content (%)

Using the Kjeldahl method, the total nitrogen content of seeds was assessed (Bremmer, 1996). The seed sample collected was grind with a tissue grinder and passed via 0.2 mm filter to produce a clear, fine powder that was used to calculate the nitrogen content. In the existence of the digestion mixture, 3 ml of concentrated H_2SO_4 was used to digest the sample seed powder, which weighed 0.2 g. The digestion was started at 50^0C and was gradually raised to 350°C until the samples' bright greenish color was achieved. As it cooled, the mixture became thinner. After being distilled with a 40 percent NaOH solution and boric acid mixed indicator, 20 mL of diluted digestion was titrated against HCl solutions and quantified after subtracting blank reading.

Determination of Proline (µg g^{-1} fresh weight)

[11] using approach, through which proline content was assessed. The homogenized 0.5g of flesh leaf sample was filtered using what man's No. 1 filter paper after being homogenized in 10ml of 3 percent aqueous sulphosalicylic acid. In a test tube, 2 ml of filtrate was added together with 2 ml of acid ninhydrin and 2 ml of glacial acetic acid. This was placed in a bath of boiling water and let an hour to react at

1000C. By putting the tube in an ice box, the reaction was stopped. The mixture for the reaction received 4 ml. Toluene was used as a blank to measure absorbance at 520 nm while the toluene-containing chromophore was separated.

It is calculated by the formula:

[(µg proline/ml X ml toluene)/115.5µg/µmole]/ [(g sample)/5] = µmoles proline/g of fresh weight

Determination of Hydrogen Peroxide (H_2O_2)

For the determination of hydrogen peroxide content the method described by [77] was applied to assess the hydrogen peroxide. After homogenizing 500 mg of leaf tissue with 5.0 ml of trichloroacetic acid (TCA), the mixture was quickly cool in an ice bath. The supernatant was then collected after 15 minutes of centrifugation at 12000 g. 1.0 ml of potassium iodide (1M) and 0.5 ml of 10 mM phosphate buffer (pH 7.0) were added after 0.5 ml of supernatant was transferred to a test tube. After the addition, the solution was thoroughly mixed, and the absorbance at 390 nm was noted. With an extinction coefficient (E) of 0.28 µ m^{-1} cm^{-1}, the amount of H_2O_2 was calculated and represented as n mol g^{-1} fresh weight.

Statistical analysis

I. The data was statistically analyzed using techniques of analysis of variance for randomized complete block design. When the F-values were significant, the means were compared using the LSD test at the 0.05 level of probability Steel and Torrie [69]

II. .Results

III. Nodules plant^{-1}

IV. The data in Table 1 relates to nodules plant^{-1} of mungbean as impacted by foliar spray of salicylic acid and seed priming of molybdenum. Spray application significantly enhanced the number of nodules plant^{-1} of the mungbean crop. The interactive effect of salicylic acid and molybdenum seed priming were found non-significant. More (20) nodules plant^{-1} were noted by a SA foliar spray of 300 mg L^{-1}, which was statistically comparable to a spray of 200 mg L^{-1}. In control plots, the minimum (17) nodules plant^{-1} was noted. Minimum (15) nodules plant^{-1} were reported in unprimed seeds plots, which were statistically similar to water priming plots. Among different molybdenum seed priming levels, treatment with molybdenum at a rate of 93 mg L^{-1} followed by 279 mg L^{-1} of molybdenum resulted in the production of more nodules plant^{-1}.

v. Thousand seed weight (g)

VI. A statistical analysis of the data revealed that the molybdenum seed priming and salicylic acid foliar spray had a significant impact on the mungbean thousand seed weight. SA x Mo were found non-significant (Table 1). SA foliar spray at the rate of 200 mg L^{-1} resulted in heavier grains (36.3 g), which were statistically comparable to 300 mg L^{-1} of SA foliar spray. In control plots, lighter (32.6 g) thousand seed weight was observed. Molybdenum seed treatment at a rate of 279 mg L^{-1} yielded maximum (37.0 g) thousand seed weight which is statistically comparable to 186 mg L^{-1} of priming molybdenum. The weight of the thousand seeds in the control plots, however, was lower (32.8 g).

VII. Biological yield (kg ha^{-1})

VIII. Table 1 shows that salicylic acid foliar spray and various molybdenum seed priming levels affect mungbean biological yield statistics. The data analysis showed that the biological yield was significantly impacted by salicylic acid foliar spray and molybdenum seed priming. SA x Mo was found non-significant for the biological yield of the mungbean crop. Salicylic acid foliar spray in the of 200 mg L^{-1} recorded the maximum (2852 kg ha^{-1}) biological yield followed by salicylic acid foliar spray (2766 kg ha^{-1}) in the amount of 300 mg L^{-1}. In untreated plots, minimum (2597 kg ha^{-1}) biological yield was attained. Higher (2973 kg ha^{-1}) biological yield was achieved by priming with molybdenum at a rate of 279 mg L^{-1} followed by 186 mg L^{-1} of molybdenum (2788 kg ha^{-1}). In untreated plots, a lower (2552 kg ha^{-1}) biological yield was noted.

IX. Seed yield (kg ha^{-1})

X. A statistical analysis of the data is shown in Table 1, which demonstrates that foliar salicylic acid spraying and molybdenum seed priming greatly boosted mungbean seed yield. The interactive effect of salicylic acid and seed priming was found to be non-significant. The maximum (726 kg ha^{-1}) and (693 kg ha^{-1}) seed yield were obtained with 200 mg L^{-1} of salicylic acid foliar spray and 300 mg L-l of salicylic acid foliar spray, respectively. Control plots produced the least seeds (605 kg ha^{-1}). A higher (783 kg ha^{-1}) seed yield was obtained priming with 279 mg L^{-1} molybdenum as compared with 186 mg L^{-1} molybdenum (736 kg ha-l). Untreated plots had minimum (569 kg ha-l) seed yield which was statistically similar to the water priming treatment.

XI. Harvest index (%)

XII. Table 1 shown mungbean harvest index. Data analysis revealed that molybdenum seed priming and salicylic acid foliar spray had a significant influence on the harvest index of the mungbean crop. SA x Mo seed priming were found non-significant. The maximum (25%) harvest index was attained with foliar spray of 300 mg L^{-1} salicylic acid followed by 200 mg L^{-1} salicylic acid foliar spray (24%). A minimum (22%) harvest index was reported in control plots. A maximum (25%) harvest index was obtained by molybdenum priming at a rate of 279 mg L^{-1}, which was statistically comparable to 186 mg L^{-1} of molybdenum. Control plots yielded a lower harvest index (21%) compared to other plots.

XIII. Soil total nitrogen content (%)

XIV. Salicylic acid foliar spray application and molybdenum seed priming considerably enhanced soil total nitrogen content, according to data in Table 2 that have undergone statistical analysis. The interactive effect of SA and Mo seed priming were found insignificant. The highest (0.069%) soil total nitrogen content was recorded with 300 mg L^{-1} of salicylic acid foliar spray, which was statistically similar to 200 mg L^{-1} of salicylic acid foliar spray. The total nitrogen content of the soil was lower (0.064%) in control plots. The highest (0.073%) soil total nitrogen content was attained by molybdenum priming at a rate of 279 mg L^{-1}, which was followed by 186 mg L^{-1} of molybdenum-primed seeds (0.070%). While control plots produced lower (0.062%) soil total nitrogen content.

XV. Seed nitrogen content (%)

XVI. Data related to seed nitrogen content of mungbean as affected by salicylic acid foliar spray and seed priming with molybdenum is shown in Table 2. Statistical analysis of the data showed that the application of molybdenum seed priming and salicylic acid foliar spray had a significant influence on seed nitrogen content. The interactive effect of salicylic acid and molybdenum were found non-significant. Maximum (3.0%) seed nitrogen content was noted with 300 mg L^{-1} of salicylic acid foliar spray, similar to 200 mg L^{-1} of salicylic acid foliar spray. In control plots, the minimum (2.6%) seed nitrogen content was attained. More (3.5%) seed nitrogen content was obtained by molybdenum seed priming at a rate of 279 mg L^{-1} compared to 186 mg L^{-1}. While in control plots there was a lower (2.4%) seed nitrogen content.

XVII. Seed crude protein content (%)

XVIII. Data related to seed protein content as effected by seed priming with molybdenum and salicylic acid spray. Statistical analysis depicted that seed priming with molybdenum has a significant influence on seed protein content. SA x Mo were shown to be non-significant for the seed protein content of mungbean crops. Among molybdenum priming levels, maximum (20.5%) seed protein content was reported with 279 mg L^{-1} of molybdenum priming and 186 mg L^{-1} of molybdenum priming. Seed protein levels were lower (14.4%) in the control plots. As concerned to salicylic acid dipected non-significant effect on seed crude protein content

XIX. Proline (µg g^{-1} fresh weight)

XX. The data analysis showed that the proline content was significantly influenced by both molybdenum seed priming and salicylic acid foliar spray. SA x Mo was shown to be insignificant for the proline content. Salicylic acid foliar spray in the amount of 200 mg L^{-1} recorded maximum (0.792 µg g^{-1}) proline concentration which was followed by 300 mg L^{-1} of salicylic acid foliar spray (0.614 µg g-1). In untreated plots, minimum (0.348 µg g^{-1}) proline content was formed. Among molybdenum levels, maximum (0.670 µg g^{-1}) proline content was obtained by priming with molybdenum at a rate of 279 mg L^{-1} as compared to 186 mg L^{-1}. In untreated plots, a lower (0.478 µg g^{-1}) proline content was observed. XXXI. XXXII. XXXIII.

XXI. **Hydrogen Peroxide (nmol g^{-1} FW)** XXXIV.

XXII. Mungbean hydrogen peroxide data is influenced by different molybdenum seed priming levels and salicylic acid foliar spray is represented in Table 2. The analysis showed that molybdenum seed priming and salicylic acid foliar spray had significant effects on hydrogen peroxide. The SA x Mo was found to be significant for the hydrogen peroxide of the mungbean crop. With 100 mg L-1 of salicylic acid foliar spray, higher hydrogen peroxide (1.03 nmol g^{-1}) fresh weight of leaves was noted, followed by 200 mg L^{-1} of salicylic acid foliar spray (0.749 nmol g^{-1}) fresh weight. In untreated plots, less hydrogen peroxide (0.591 nmol g^{-1}) was recorded. As concerned to molybdenum maximum (0.896 nmol g^{-1}) hydrogen peroxide was attained with molybdenum priming at a rate of 93 mg L^{-1} than by water priming (0.768 nmol g^{-1}). In untreated plots, lower (0.651 nmol g^{-1}) hydrogen peroxide was seen.

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XXXV. **Table 1**. Nodules plant^{-1}, Seeds pod^{-1}, thousand seeds weight (g), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index (%) were affected by molybdenum seed priming and salicylic acid foliar spray.

Mo (mg L^{-1})	Nodules plant^{-1}	Seeds pod^{-1}	1000 seeds wt (g)
Unprimed	15 d	5 d	31.8 c
water priming	15 d	5 d	32.3 bc
93	20 c	7 c	32. 2 b
186	22 b	8 b	35.0 a
279	24 a	9a	36.0 a
LSD (0.05)	1.31	0.55	1.09
SA(mg L^{-1})			
Control	17 c	6 c	31.6 c
100	19 b	6 c	32.8 b
200	20 a	8a	35.3 a
300	20 a	7 b	34.9 a
LSD (0.05)	1.17	0.49	0.98
Mo x SA	Ns	ns	Ns

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XLIX. **Table 2.** Soil total nitrogen (%), seed nitrogen (%), crude protein (%), proline content (µg g^{-1} fresh weight) and H_2O_2 (nmol g^{-1} fresh weight) were affected by molybdenum seed priming and salicylic acid foliar spray.

Mo (mg L^{-1})	Soil total N (%)	Seed N (%)	Crude protein (%)	Proline (µg g^{-1} FW)	H_2O_2 (nmol g^{-1} FW)
Unprimed	0.062 d	2.4 d	14.4 c	0.478 d	0.651 d
water priming	0.062 d	2.5 d	14.6 c	0.527 c	0.768 b
93	0.067 c	2.8 c	16.4 b	0.528 bc	0.896 a
186	0.070 b	3.3 b	20.4 a	0.56 b	0.724 c
279	0.073 a	3.5 a	20.5 a	0.67 a	0.74 bc
LSD (0.05)	0.0013	0.16	1.04	0.061	0.063
SA(mg L^{-1})					
Control	0.064 c	2.6 b	16.8	0.348 d	0.591 d
100	0.066 b	2.9 a	16.8	0.454 c	1.03 a
200	0.068 a	3.0 a	17.8	0.792 a	0.749 b
300	0.069 a	3.0 a	17.7	0.614 b	0.653 c
LSD (0.05)	0.0012	0.14	Ns	0.055	0.056
Mo x SA	ns	ns	Ns	ns	0.126

Discussion

L. Molybdenum seed priming and salicylic acid foliar spray had a significant influence on the nodules $plant^{-1}$ of mungbean. By treating seeds with 279 mg Mo L^{-1}, maximum nodules $plant^{-1}$ were produced. The nitrogenase enzyme, which is essential for biological nitrogen fixation, molybdenum considered integral component of the enzyme [24]. After seed priming with molybdenum improved the development of nodules in legumes [69]. Nodule development in the mungbean provides nutrients to the plant and improves the production of seeds in the mungbean pods [8, 67, 50]. Nodules $plant^{-1}$ increased linearly with increasing salicylic acid spray. With the application of 300 mg L^{-1} application of salicylic acid nodules $plant^{-1}$ increased. It may be because of salicylic acid sprays which enable the plants resilient to drought stress, especially during nodule formation, which boosted the number of nodules and the performance of mungbean plants [63].

LI. Thousand seeds weight of mungbean was substantially enhanced by the foliar applied salicylic acid and molybdenum priming. Mungbean seeds treated with molybdenum at the rate of 279 mg L^{-1} due to which availability N increased to mungbean plants and consequently increases seed weight. Our outcomes are in line with [63] who reported that mungbean thousand seed weight increased with molybdenum application. Molybdenum-treated seed improved the metabolic processes of mungbean plants and raised the weight and quantity of pods on each plant, increasing the economic output of mungbean in comparison to untreated seed [73, 52]. A 200 mg L^{-1} salicylic acid foliar spray resulted in 11% greater grain weight as compared to control plots. The possible argument might be that photosynthetic activity accumulation improved during growth and development, which led to the production of the features that provided the highest yields, such as thousand grains weight [54]. [45] reported a similar set of data, who reported that heavier thousand grains weight were attained by applying salicylic acid spray at a rate of 0.3 g L^{-1} in compared without spray plots.

LII. The biological yield was significantly influenced by the application of molybdenum priming and salicylic acid spray. Mungbean with 279 mg Mo L^{-1} yield was improved linearly by molybdenum seed priming. This might be a result of increased chlorophyll production in the leaves, which promoted photosynthesis and raised plant characteristics, increasing mungbean grain and biological yield in the process [69]. Biological yield was enhanced by molybdenum priming because of extended germination and evenly distributed mungbean growth, which results in increased dry matter production of mungbean [12]. Our results confirmed by [74] who noted that seed priming with molybdenum in the amount of 400 mg L^{-1} promote biological yield. The maximum biological yield was achieved with foliar application of salicylic acid in the amount of 200 g L^{-1} compared to control plots. Increased biological output of mungbean may have occurred as a result of salicylic acid controlling photosynthesis of plant, proline and nitrogen metabolisms, antioxidant enzyme activity and plant resistance to abiotic stimuli such high temperatures and drought [43, 55]. The biological yield of mungbean was considerably influenced by the foliar application of salicylic acid, whereas control plots resulted minimum biological yield [27].

LIII. Grain yield of mungbean increased with the foliar application of salicylic acid and molybdenum priming. Seed priming at the rate of 279 mg Mo L^{-1} increased the grain yield of leguminous crop by maintaining soil nutritional position [8, 67, 63]. Inoculation, priming, and the application of molybdenum contributed to the largest harvest index, which was also the most economical yield [2]. Mungbean grain production increased by molybdenum-treated seed, which also significantly improved the yield characteristics of the crop [57]. Salicylic acid at the rate of 200 mg L^{-1} foliar spray increased grain yield by 22% when compared to control plots. Exogenous salicylic acid enhanced plant development and production. Low SA concentrations were sprayed on mustard plants, which produced maximum dry matter and had efficient photosynthesis than control plants [40, 20].

LIV. The harvest index of the mungbean crop was positively influenced by molybdenum priming and salicylic acid foliar spray. The harvest index measures the biological yield to economic yield of a crop. In comparison to control plots, the molybdenum applied in the amount of 279 mg L^{-1} considerably boosted plant growth, seed yield, and dry matter production [12]. Our findings are in line with [29], who found that seed treated with molybdenum had a substantial impact on harvest index when compared to control. The harvest index of the mungbean crop was significantly increased by priming with molybdenum at rates of 0.6 and 0.3 g L^{-1} [17]. Molybdenum seed priming significantly boosted the plant's ability to produce dry matter, grain yield, and biomass, all of which contributed to the crop's higher harvest index [12]. The harvest index of mungbean was significantly higher after salicylic acid spray applied at the rate of 300 mg L^{-1} compared to control. Similar results were reported by [40] who found that salicylic acid 0.3 g L^{-1} enhanced mungbean harvest index when administered as a foliar due to effective nutrient usage during life cycle. Our findings are in line with those of [49] who reported that salicylic acid enhanced harvest index of mungbean.

LV. Soil total nitrogen significantly affected by salicylic acid foliar spray and molybdenum priming application had a significant influence on soil total nitrogen content. When compared to control plots, seed priming with 279 mg L^{-1} molybdenum resulted in an 8.6% increase in soil total nitrogen, while 300 g L^{-1} salicylic acid applied as a foliar spray increased soil total nitrogen by an additional 18.6% (no spray). Our findings were similar with those of [28] who affirmed that molybdenum-treated seed significantly boosted the soil's total nitrogen content. Application of priming with molybdenum could increase soil total N in comparison to control [32]. Salicylic acid applied at a rate of 200 mg L^{-1} conserved an enhanced in soil total nitrogen of 8% above the control. Salicylic acid applied as foliar enhanced the amount of nitrogen in the soil [7, 44]. Our results are confirmed by [23] who revealed that salicylic acid significantly increased the amount of total nitrogen in the soil.

LVI. A foliar spray of salicylic acid at a dosage of 300 mg L^{-1} yielded a maximum seed N content in the soil of 42.3% as compared to control plots, while seed treated with 279 mg L^{-1} molybdenum resulted in a seed N content of 15% compared to control plots (no spray). According to [3] seed treatment with molybdenum at a rate of 400 mg L^{-1} could increase the nitrogen content in mungbean seed. Mungbean seed priming with molybdenum increase the amount of nitrogen in the seeds [62]. [28] reported similar findings that seed total nitrogen can be increased as a result of using molybdenum seed priming. Salicylic acid foliar application at the rate of 300 mg L^{-1} sustained a 6% increase in seed nitrogen content as compared to untreated plots. A higher seed N content was obtained when salicylic acid 0.2% was applied as a foliar spray [30].

LVII. According to the findings, molybdenum boosts protein content and nitrogen fixation, which increases mungbean production and yield composition. The protein content of mungbean seed primed with molybdenum at a rate of 279 mg L^{-1} was substantially higher than that of the control. Where molybdenum is applied, for example, improved nitrogen and phosphorus availability improves overall quality metrics, which could explain the higher protein content [52]. The major goal of the present investigation may be to increase the availability of molybdenum, which is essential for nitrate reductase production and activity. Molybdenum (Moco) is a cofactor needed by nitrate reductase to bind to different Apo proteins [61].

LVIII. Seed priming with molybdenum and salicylic acid foliar spray had a substantial impact on data pertaining to proline concentration in leaves of mungbean crop. Using molybdenum at a dose of 279 mg L-l during priming revealed the highest proline concentration. Similar results were reported by [26] who narrated that proline content increased in mungbean crop due to priming as compared with no priming. The possible reason could be that molybdenum has significant role in nitrogen fixation [47]. Salicylic acid spray application at the rate of 200 mg L^{-l} enhanced proline content in leaves of mungbean crop in association with control plots. [61] reported similar results that salicylic acid 200 mg L^{-l} improved proline content in leaves mungbean crop. [65] showed that salicylic acid up to certain level increase proline content in leaves of mungbean crop as compared with rest treatments. The possible argument may be that salicylic acid enhances photosynthetic activity and plant growth under stress but especially under slat stress [47]. Our outcomes are supported by [30] and [33] that SA increase proline content in mungbean leaves.

LIX. Data pertaining to hydrogen peroxide in mungbean crop leaves were considerably impacted by foliar seed priming with molybdenum and salicylic acid. Molybdenum priming at the amount of 93 mg L^{-l} hydrogen peroxide in leaves of mungbean as compared to other treatments. Our results were in line with [26] who reported that hydrogen peroxide slightly improve in mungbean leaves up to certain level of Mo application as compared to the rest of treatments and then decrease rapidly. This increase due to priming which improve enzymatic and non-enzymatic defence systems [76]. Similar results were also recorded by [22] that Mo enhanced H_2O_2 in mungbean leaves. Foliar application of salicylic acid 100 mg L^{-l} enhanced H_2O_2 in leaves of mungbean crop in comparison with control plots. Our findings are in line with [43] that SA foliar application decrease H_2O_2 in mungbean leaves. [65] that minimum foliar spray salicylic acid reported maximum H_2O_2 in leaves of mungbean.

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LXII. CONCLUSION

LXIII. It is concluded that mungbean seeds priming with molybdenum @ 279 mg L^{-1} and salicylic acid foliar application @ 200 mg L^{-1} attained maximum seed yield and therefore recommended for the studied area.

APPENDIX

Appendixes, if needed, appear before the acknowledgment.

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