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Effect of Soil Moisture Content and Mycorrhiza Dosage on Available Phosphorus, Growth, and Yield of Sweet Corn

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ABSTRACT: This study aims to determine the effect of interaction between water content and mycorrhiza dose on growth, yield, and phosphorus (P) availability in sweet corn plants (Zea mays saccharata Sturt). The research was conducted in the Green House of the Faculty of Agriculture, Udayana University using a factorial complete randomized design (CRD) with two factors: water content (K0, K1, K2, K3) and mycorrhiza dose (M0, M1, M2). The results showed that the interaction of water content and mycorrhiza had a very significant effect on plant height, number of leaves, stem diameter, root length, number of roots, leaf chlorophyll, and phosphorus availability. The best treatment was obtained in the combination of water content of 40% field capacity (K3) and mycorrhiza dose of 20 g/plant (M2), which resulted in optimal plant growth even under water stress conditions. Mycorrhizal symbiosis is proven to increase water and nutrient uptake, improve soil structure, and increase plant

KEYWORDS: Water Content, Mycorrhiza, Sweet Corn.

INTRODUCTION

Sweet corn (Zea mays saccharata Sturt) is an important horticultural commodity that requires optimal nutrient and water availability to achieve maximum yield. [1] The average productivity of sweet corn in Indonesia only reaches 6 tons per hectare, while developed countries such as the United States are able to achieve productivity of up to 10 tons per hectare. The main challenges in corn cultivation are limited water availability and low phosphorus availability in the soil. Arbuscular mycorrhiza has been widely recognized as being able to form a mutualistic symbiosis with the host plant, expand the root uptake area through external hyphae, and increase nutrient and water absorption efficiency.

Soil moisture content is also an important factor affecting mycorrhizal activity and phosphorus availability. Optimal soil moisture content allows mycorrhizal activity to take place optimally, thus supporting plant growth and yield. [2] showed that the combination of optimal moisture content with mycorrhiza application increased corn plant growth by 25% compared to conditions without such treatment. Good water content management not only helps mycorrhizal activity, but also prevents water stress in plants, which can inhibit plant physiological processes [3]. Lack of available phosphorus in the soil can limit plant growth, as phosphorus is an essential element in energy formation (ATP), DNA and RNA synthesis, as well as root formation and photosynthesis processes. In addition, limited water in the field often causes physiological stress that inhibits plant growth and productivity. [4], Mycorrhiza can help plants survive water stress conditions by increasing the ability of roots to absorb water. Under these conditions, the use of biological technology such as mycorrhiza can be an effective solution because it can increase the adaptability of plants to abiotic stress through increased water and nutrient use efficiency.

Previous studies have shown that mycorrhiza can improve plant growth, increase the number and length of roots, and increase nutrient availability through symbiotic activities that help absorb nutrients from soil fractions that are difficult for roots to reach. Therefore, this study aimed to evaluate the effect of a combination of water content and mycorrhiza dosage on growth, yield, and available P in sweet corn plants, so as to provide alternative cultivation technologies adaptive to water stress and nutrient deficiencies.

RESEARCH METHOD

The research location was at the Green Hause Experimental Garden of the Faculty of Agriculture, Udayana University on Jl. Pulau Moyo No.16X Pedungan, South Denpasar, Bali. The research time was from November to December. This study used experimental pots with a two-factor factorial completely randomized design (CRD). The first factor is moisture content (K) consisting of 4 levels, namely: K0 = control or field capacity moisture content (100%), K1 = 80% moisture content, K2 = 60% moisture content, K3 = 40% moisture content, The second factor is the dosing of mycorrhiza (M) with 3 levels, namely: M0 = (control) mycorrhiza dose of 0 g/plant, M1 = mycorrhiza dose of 10 g/plant, M2 = mycorrhiza dose of 20 g/plant. there are 12 treatment combinations with 3 replicates, so there are a total of 36 plants. The data obtained will be analyzed using the analysis of variance (ANOVA) method used to determine the effect of water content treatment and mycorrhiza dosage on the observed variables. If there is a significant effect, followed by further tests such as the honest real difference test (BNJ) to determine differences between treatments. The planting medium used in this study was soil taken from the Experimental Garden of the Faculty of Agriculture, Udayana University and air-dried. The air-dried soil was then sifted and filled in polybags with a size of 40x40 cm with a weight of 10 kg. In the research preparations were made at the time of planting, the seeds used were F1 type. Mixed directly with mycorrhiza according to the dose and ready to be planted on the media by ditugal into the soil depth of 2-3 cm. Determination of the level of drought stress was carried out by determining the field capacity water content for each treatment polybag. Field capacity soil moisture content was determined by using 1 polybag of sweet corn plants as a sample. Each polybag was watered with excess water and left for 24 hours. The water dripping from the bottom of the polybag was collected and calculated the volume then averaged and repeated 3 times. Soil moisture content in sweet corn polybags is analogous to being at field capacity by reducing the volume of excess water applied with water dripping from the bottom of th e polybag. This means that to make the field capacity soil moisture content in each polybag, it is necessary to water the amount of excess water volume applied with the volume of water dripping from the average of 3 polybags used as samples and repeated twice to determine the field capacity moisture content. After calculating the average, the amount (Aml) of water needed to make the field capacity was obtained.

Field capacity was determined two days before seed planting. The drought stress level treatment was carried out by: for the control level, the plants were not given drought stress or 100% field capacity water content (A ml x100/100), drought stress with 80% field capacity water content (A ml x80/100), drought stress with 60% field capacity water content (A ml x60/100) and; drought stress with 40% field capacity water content (A ml x40/100), watering was done every two days with a fixed volume of water according to the measured field capacity. Corn seeds were planted 2 grains per planting hole by tugal 2-3 cm deep then the soil hole was closed and leveled again, the distance between polybags was 40 cm, after 7 days it was necessary to replant to replace seeds that did not grow in order to maintain the same number of plant populations. Weeding uproots weeds that are between the plants and at the same time loosens the soil, weeding is done clean up according to the development of weeds, this activity aims to reduce competition in nutrient absorption, reduce barriers to sweet corn production and reduce competition for sunlight penetration.

Pest and disease control is an action to ensure that plants remain healthy plants and provide good production, to prevent pests and diseases in sweet corn plants through sanitation and maintain cleanliness in the research site, if there is a pest or disease failure, it is sufficient to use physical and mechanical control The harvest age of sweet corn plants varies depending on the variety and growing environment. In this study, harvesting was carried out under fresh conditions with an estimated corn age of 72-75 HST marked by dark green skin color on the corn cob.

RESULTS

Plant Height, Stem Diameter, Number of Leaves.

Based on the data listed in table 1, the interaction effect between the water content factor and the mycorrhiza factor on corn plant height, stem diameter and number of leaves. In the combination of water content K0 and M0 (without mycorrhiza), corn plant height was recorded at 225.33 cm, 204.33 cm for M1, and 207.00 cm for M2. At water content K1, corn plant height showed higher results, namely 222.67 cm for M0, 213.00 cm for M1, and 227.67 cm for M2. In water content K2, although there was a decrease in M0 and M1, the height of corn plants in M2 increased again to 227.33 cm. Meanwhile, at K3 moisture content, which showed the highest results in all categories, corn plant height was recorded at 193.33 cm for M0, 217.33 cm for M1, and 229.67 cm for M2. Based on the value of (Differential Real Honest) at the 5% significance level, which amounted to 33.77 cm, the combination of water content and mycorrhiza can have a very significant effect on plant height. Based on the data listed in table 2, the interaction between water content and mycorrhiza on sweet corn stem diameter. At water content K0, the diameter of corn stalk was recorded at 1.77 cm in M0, 1.80 cm in M1, and 2.13 cm in M2. At moisture content K1, the diameter of corn stalks was larger, 1.83 cm at M0, 2.00 cm at M1, and 2.17 cm at M2. At water content K2, the diameter of corn stalks was recorded at 1.73 cm in M0, 2.03 cm in M1, and 2.20 cm in M2. While at moisture content K3, the diameter of corn stalks was smaller in M0

(1.63 cm), but increased in M1 (1.87 cm) and M2 (2.15 cm). Based on the value of (Differential Real Honest) at the 5% significance level which amounted to 0.12, the difference in corn stalk diameter between the combination of water content and mycorrhiza had a very significant effect.

The interaction between water content and mycorrhiza on the number of leaves of corn plants. At water content K0 (control), mycorrhiza treatment M2 produced the highest number of leaves (13.33 leaves), followed by M1 (12.33 leaves) and M0 (11.33 leaves), indicating that mycorrhiza M2 has the potential to increase the number of leaves of corn plants. At moisture content K1, the number of leaves did not differ much between treatments M0 and M1, each having 12.00 leaves, while M2 was slightly higher with 12.33 leaves. At moisture content K2, mycorrhizal treatments M1and M2showed similar higher number of leaves (13.00 and 13.33 leaves), compared to M0 which only reached 9.33 leaves. which only reached 9.33 leaves. At K3moisture content, although mycorrhizae M1and M2showed slightly higher results (12.33 and 12.67 leaves). The value of (Honest Significant Difference) of 2.40 indicates that the difference is very significant.

Table 1. effect of water content and mycorrhiza dose on plant height variables, stem diameter, and number of leaves

Treatment	Plant height (cm)	Stem diameter (cm)	Number of leaves (strands)
K0M0	225.33 abc	1.77 ab	11.33 abc
K0M1	204.33 bc	1.80 abc	12.33 bc
K0M2	207.00 def	2.13 bcdef	13,33 f
K1M0	222.67 bcd	1.83 abcd	12.00 bcd
K1M1	213.00 ced	2.00 abcd	12.00 ced
K1M2	227.67 def	2.17 def	12.33 abcd
K2M0	196.67 abc	1,73 a	9.33 ab
K2M1	200.67 bcd	2.03 cdef	13.00 bcd
K2M2	227.33 ef	2.20 ef	13.33 def
K3M0	193,33 a	1.63 abcd	8,67 a
K3M1	217.33 abcd	1.87 def	12.33 abcd
K3M2	229,67 f	2,15 f	12.67 ef
BNJ 5%	**33,77**	**0,12**	**2,40**

Note: the numbers followed by the same letter indicate that it is not significant based on the (honest real difference test) at the 5% level.

Number of Roots, Root Length, and Leaf Chlorophyll.

This study shows the interaction effect between water content and mycorrhiza on the number of roots of corn plants. At water content K0, the number of roots of corn plants was recorded at 30.00 in M0, 32.00 in M1, and 33.00 in M2. At water content K1, the number of roots of corn plants increased to 32.67 in M0, 33.33 in M1, and 33.33 in M2. At water content K2, the number of roots of corn plants was recorded at 32.33 in M0, 33.00 in M1, and 35.00 in M2. Meanwhile, at water content K3, the number of roots of corn plants was recorded at 31.00 in M0, 33.33 in M1, and 37.33 in M2. The value of (Differential Real Honest) at the 5% significance level of 3.57 indicates that the difference in the average number of roots of corn plants between the combination of water content and mycorrhiza has a significant effect.

This study shows the interaction effect between water content and mycorrhiza on the root length of corn plants. At K0 water content, the root length of corn plants was recorded at 53.50 cm in M0, 54.80 cm in M1, and 61.43 cm in M2. At water content K1, the root length of corn plants increased to 57.30 cm at M0, 67.93 cm at M1, and 63.47 cm at M2. At water content K2, the root length of corn plants was 56.03 cm at M0, 55.27 cm at M1, and 64.20 cm at M2. While at water content K3, the root length of corn plants showed the highest results, namely 65.03 cm in M0, 67.27 cm in M1, and 84.43 cm in M2. Based on the value of (Differential Real Honest) at the 5% significance level which amounted to 25.98, the difference in the average length of corn plant roots between the combination of water content and mycorrhiza had a very significant effect.

This study shows the interaction effect between water content and mycorrhiza on chlorophyll content of corn plant leaves. At water content K0, the average chlorophyll content was 43.70 in M0, 45.63 in M1, and 47.26 in M2. At water content K1, the average chlorophyll content was 45.28 in M0, 45.63 in M1, and 47.43 in M2. At water content K2, the average chlorophyll content was 43.06 at M0, 45.25 at M1, and 50.46 at M2. While at water content K3, the average chlorophyll content showed slightly lower results at M0, which was 41.82, but increased at M1 (43.79) and M2 (49.11). The (Honest Significant Difference) value at the 5% significance level of 3.08 shows that

Table 2. the effect of water content and mycorrhiza dose on variable number of roots, length, and leaf chlorophyll.

Treatment	Number of roots (stem)	Length (cm)	Leaf chlorophyll (%)
K0M0	30,00 a	53,50 a	43.70 ab
K0M1	32.00 ab	54.80 ab	45.63 ab
K0M2	33.00 ab	61.43 ab	47.26 cde
K1M0	32.67 ab	57.30 ab	45.28 bc
K1M1	33.00 ab	67.93 ab	46.70 bcd
K1M2	33.33 ab	63.47 ab	47.43 cde
K2M0	32.33 ab	56.03 ab	43.06 ab
K2M1	33.00 ab	57.27 ab	45.25 bc
K2M2	35.00 bc	64.20 bc	50,46 e
K3M0	31,00 a	65,03 a	41.82 ab
K3M1	33.33 ab	67.27 ab	43.79 ab
K3M2	37,33 c	84,43 c	49,11 d
BNJ 5%	**3,57**	**25,98**	**3,08**

Note: the numbers followed by the same letter indicate that it is not significant based on the honest real difference test at the 5% level.

P Available

The results of soil analysis before and after mycorrhizal treatment showed an increase in phosphorus (P) availability in all soil samples tested. Before treatment, the average P content in the soil was 157.46 ppm. After mycorrhizal treatment, the P content increased variably, with the highest increase in sample K2M0, which increased from 157.46 ppm to 272.11 ppm. Similar increases also occurred in other samples, such as K0M2 (157.46 ppm to 210.57 ppm) and K3M2 (157.46 ppm to 234.53 ppm), indicating that mycorrhizal treatment was effective in increasing P availability for corn plants.

Table 3. Early and late soil analysis on soil chemical properties of available P

No.	Sample code	Initial soil analysis	Final soil analysis	Description
1	K0M0	157,46	193,07	Very high
2	K0M1	157,46	182,92	Very high
3	K0M2	157,46	210,57	Very high
4	K1M0	157,46	196,97	Very high
5	K1M1	157,46	227,26	Very high
6	K1M2	157,46	212,96	Very high
7	K2M0	157,46	272,11	Very high
8	K2M1	157,46	197,37	Very high
9	K2M2	157,46	202,71	Very high
10	K3M0	157,46	182,06	Very high
11	K3M1	157,46	228,46	Very high
12	K3M2	157,46	234,53	Very high

Type: laboratory test results before treatment and after treatment

DISCUSSION

Statistical analysis showed that there was a significant interaction between soil moisture content and mycorrhiza application on the growth and yield of corn plants. Based on observations, the K3M2 treatment (low water content with high dose mycorrhiza application) produced an average plant height of 229.67 cm, much higher than the K3M0 control treatment (without mycorrhiza) which only reached 193.33 cm. This shows that mycorrhiza plays a crucial role in supporting maize plant growth, especially under conditions of low soil moisture content which generally causes physiological stress. Vegetative growth stage, plants use water for cell division and expansion, which manifests as increased plant height, increased diameter, leaf proliferation, and root growth. Water stress conditions have an impact on reducing physiological processes in plants in the form of reduced photosynthesis rates and the amount of photosynthate produced. Water stress causes a decrease in turgor in plant cells and results in a decrease in physiological processes [5] This significant increase in growth is due to the ability of mycorrhiza to improve soil structure and expand plant root tissue through external hyphae. This hyphal network increases the plant's capacity to absorb water and essential nutrients such as phosphorus, nitrogen, and potassium, which are essential in supporting metabolic processes, photosynthesis, and vegetative growth. Statistically, the value of the (Real Honest Difference) of 33.77 at the 5% significance level indicates that the difference in plant height between treatments is significantly significant. This finding is in line with the theoretical explanation by [6] which states that arbuscular mycorrhizal fungi (FMA) are able to expand the root absorption area and increase the efficiency of phosphorus and water absorption through a mutualistic symbiotic relationship. The positive effect of mycorrhiza was also seen in the variable number of leaves of corn plants. At K0 moisture content, M2 mycorrhiza treatment produced the highest number of leaves at 13.33 leaves, compared to M1 (12.33 leaves) and M0 (11.33 leaves). This increase in the number of leaves indicates that mycorrhiza helps plants in maintaining physiological activities and the formation of vegetative organs even under water stress. Mycorrhiza forms associations with roots and expands root exploration into soil micropores that are difficult to reach by plant roots, thus allowing optimal absorption of water and nutrients. Phosphorus (P), nitrogen (N) and potassium (K) become more available to plants, and other micronutrients such as Fe, Zn, Cu and Mn are also absorbed more efficiently. Phosphorus is particularly important in ATP synthesis, DNA and RNA formation, and in supporting photosynthesis and cellular respiration. Mycorrhiza also plays a role in increasing plant tolerance to environmental stresses such as drought and salinity. This process occurs through increased water retention in plant tissues, decreased transpiration ratio, and stabilization of cell osmotic pressure. Research by [7] supports this, showing that the application of mycorrhiza increased the number of leaves and leaf area index of corn plants on calcareous land with low water content. Plants with mycorrhiza showed an increase in leaf biomass of up to 30% compared to the control without mycorrhiza. Meanwhile, [8] reported that mycorrhiza also increased the metabolism of growth hormones such as auxins and cytokinins that stimulate leaf and stem growth. Overall, the interaction between water content and mycorrhiza gave a very significant effect on

most agronomic parameters of corn plants, such as plant height, number of leaves, stem diameter. The application of high doses of mycorrhiza (M2) consistently produced the highest values on various parameters, especially when combined with optimal water content treatments K2 or K3. This indicates a synergistic effect between sufficient soil moisture and mycorrhizal activity in improving overall plant physiology. [9] showed that mycorrhiza-based biofertilizer in peatlands accelerated maize growth and yield through increased P availability and improved soil porosity. [10] also added that mycorrhizal external hyphae are able to penetrate soil micro pores that are not reached by roots, increasing water absorption capacity under low moisture content conditions. This finding was reinforced by [11], who showed that mycorrhiza is effective in reducing the impact of environmental stress, such as drought and salinity, through improving plant water status and strengthening the root system. Recent research by [12] in *Environmental Technology & Innovation* confirms that inoculation of maize plants with arbuscular mycorrhizal fungi not only increases drought resistance, but also strengthens antioxidant activity and stimulates rhizosphere microbial communities that support plant health and physiological efficiency. Furthermore, the interaction between water content and mycorrhizal factors was shown to affect root number, root length and leaf chlorophyll of corn plants. The data showed that the combination of high dose mycorrhiza treatment M2 with various levels of water content tended to produce more optimal plant height compared to the treatment without mycorrhiza (M0) or low dose (M1). The highest plant height was recorded in the K3 water content treatment and M2 mycorrhiza, which amounted to 229.67 cm, which exceeded the 5% BNJ value by 33.77 cm. This pattern of increase was consistent across all moisture content levels, indicating the effectiveness of mycorrhiza in improving plant growth, even under limited moisture content conditions. This is in line with research [13] which shows that mycorrhiza is able to minimize the effects of environmental stress and increase the activity of growth hormones such as auxins and cytokinins that play a role in stem elongation. This suggests that mycorrhiza not only supports vegetative tissue formation but also protects plants from water stress by expanding the root absorption zone.

The role of mycorrhiza in increasing stem diameter can be explained through its ability to increase the uptake of essential nutrients such as phosphorus and potassium, and strengthen the structure of plant tissues. Mycorrhiza also increases water availability in the root zone, allowing plants to maintain optimal cell turgor, thus supporting the process of stem cell division and enlargement. This effect appeared significant at the M2 dose at various water levels, including under water stress conditions (K3), which showed a diameter value of 2.15 cm, much higher than M0. This finding was reinforced by [14] who reported that mycorrhiza application at the right dose significantly increased sweet corn stem diameter, especially when combined with efficient watering times. Meanwhile, internationally, [15] revealed that mycorrhiza not only improves soil structure and nutrient availability, but also directly promotes stronger stem growth through optimizing the root system and increasing plant growth hormones.

CONCLUSION

The interaction between water content and mycorrhiza dosage gave a very significant effect on all growth and yield parameters of sweet corn, including plant height, number of leaves, stem diameter, length and number of roots, chlorophyll content, and available P content. The best treatment was obtained in the combination of K3M2 (40% field capacity moisture content and 20 g/plant mycorrhiza), which consistently increased vegetative growth and soil P availability. Arbuscular mycorrhiza is able to increase the efficiency of nutrient and water uptake, and increase plant tolerance to drought stress.

ADVICE

1. The use of high doses of mycorrhiza (20 g/plant) is highly recommended especially under water stress conditions to support optimal growth of sweet corn plants.
2. Further research is recommended to be conducted in open fields with different agroecosystem conditions to assess the consistency of mycorrhizal effectiveness at the field scale.
3. Evaluation of local mycorrhizal species or combinations with other biofertilizers can expand the potential application of this environmentally friendly technology in sustainable agriculture.

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