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Research Article

Growth and yield responses of two cowpea (*Vigna unguiculata* L.) varieties on different irrigation levels

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ABSTRACT

Cowpea (Vigna unguiculata L.) or kacang tunggak in Indonesian belongs to the Leguminoceae family and is recently still a less commercial crop. This study was conducted to determine irrigation volume based on pan evaporation and its effects on the growth, yield, and irrigation water use efficiency (IWUE) of cowpea (Vigna unguiculata L.) grown in the plastic house. The amount of water applied was based on pan evaporation (Eo). This experiment used a split-plot randomized complete block design; the main plot was cowpea varieties (Albina and Uno), and subplots were irrigation volume (0.75, 1.50, 2.25, and 3.0 Eo). The data were subjected to analysis of variance; then, the means were compared using Duncan's Multiple Range Test (DMRT). All tests were considered significant at p < 0.05. The experimental results showed that the water requirement during the vegetative phase for 5 consecutive weeks for the Albina variety was 2.91 Eo, 3.0 Eo, 3.0 Eo, 3.0 Eo, and 2.11 Eo; for the Uno variety was 3.0 Eo, 3 .0 Eo, 3.0 Eo, 2.94 Eo, and 2.10 Eo, respectively. For the Albina and Uno varieties at the generative phase, the plant water requirements were 1.66 Eo and 1.79 Eo, respectively. In cowpea farming, the optimum treatment for efficient water use or lowest usage of water was determined to be 2.25 Eo of irrigation volume combined with the Albina variety. Cowpea growth and productivity are significantly impacted by irrigation volume.

Keywords: Albina variety; evaporation; kacang tunggak; Uno variety; water efficiency

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INTRODUCTION

Cowpea (*Vigna unguiculata* L.) or *kacang tunggak* in Indonesian belongs to the Leguminoceae family and is recently still a less commercial crop. Cowpea is native to Africa, and about 97% of world production originates in African regions (Osipitan et al., 2021). The seed is nutritious and contains sufficient protein and low-fat content therefore it is used as food and feed crops in many regions (Enyiukwu et al., 2018).

In Indonesia, cowpea is considered tolerant to drought, it is easy to cultivate and grows well in low-fertility soil (Kasno et al., 2001). As a result, it is promoted as a complement to soybean by some societies. However, its cultivation method especially in relation to water requirements is still unclear.

According to farmer information, legume plants including cowpeas do not grow well in environments with excessive or shortage of water. Even though rainfall in dry climates is relatively low, intense rainfall during the rainy season can cause waterlogging. In soybean, Candogan et al. (2013) stated that seed production decreased along with increasing drought stress in soybean plantings. Previously, Mapegau (2006) stated that varieties and the level of water interacts on growth and yield traits of soybean. Therefore, it is understandable that soybean production on acid dry land (classified as marginal dry land) in Indonesia is generally low due to limited soil fertility and water availability. Hafif and Santi (2016) noted that nutrient and water availability determine the growth and fertility of soybean. Suryanti et al. (2015) stated that increasing watering intervals significantly reduces water use efficiency in soybean plants. Therefore, managing water is important in legume production including cowpea. It is also important to determine the right time and amount of irrigation water to increase irrigation efficiency.

Herawati et al. (2018) stated that the influence of water when giving water every two days produced the highest total and actual yield of grain production of 5.32 tons ha^{-1}, the lowest with giving water every 30 days was 2.62 tons ha^{-1} and the interaction of water giving intervals and varieties affect on the number of productive pods. This study was conducted to determine irrigation volume based on pan evaporation and its effects on the growth, yield, and irrigation water use efficiency (IWUE) of cowpea grown in the plastic house.

MATERIALS AND METHODS

The experiment was conducted in a plastic house at Cikabayan Experimental Field, Bogor, Indonesia from January to April 2022. The average temperature and air humidity during the planting period ranged from 30-32 °C and 76-80%, respectively, indicating suitable for cowpea growth. Production components and moisture content were analyzed at the Postharvest Laboratory of the Department of Agronomy and Horticulture.

The materials used in this study were Albina and Uno varieties of cowpea. The 14-day-old seedlings were transplanted in polybags sized 40 cm x 40 cm and a diameter of 28 cm, and the bag was arranged at a distance of 50 cm. Before the cowpeas were transplanted into polybags, irrigation was carried out until percolation occurred. Plant maintenance included watering, weeding, hiling up, and pest control. Harvest was done at 8 weeks after transplanting (WAP).

The experimental design was arranged in a split-plot randomized complete block design (RCBD) with the main plot being cowpea varieties (Albina and Uno) and the sub plot was the level of plant water requirements (0.75x Eo; 1.50x Eo; 2.25x Eo and 3.00x Eo). The treatments were four irrigation volumes based on pan evaporation (EoA), i.e., 0.75, 1.50, 2.25, and 3.00 Eo. Pan evaporation values were obtained by measuring the decrease in water height in the evaporation pan. Irrigation volume was calculated by multiplying the surface area of the pot by 0.75, 1.50, 2.25, and 3.00, respectively. The experiment consisted of 4 replications and 8 treatment combinations totaling 32 experimental units. Albina dan Uno was selected because they exhibit tolerance to drought, are simple to cultivate, and grow well on low-fertility soil.

Every two days, irrigation treatment was performed using a volume of water based on the watering method stated by Sulistyono & Juliana (2016). The irrigation volume formula (cm^3) was as follows: VI = Eo x A x Ko; VI stands for volume irrigation; Eo was the pan evaporation; A was the polybag's surface area; and Ko was the irrigation treatment coefficient (0.75, 1.50, 2.25, and 3.00).

Before applying irrigation, the pan's evaporation was measured every two days. This pan evaporation figure depends on the Allen et al. (1998) water balance calculation. P = Eo + ΔH, where P was rainfall (mm), Eo was pan evaporation (mm), and ΔH was the change in the pan's water height (mm). The research was conducted in a plastic house to prevent precipitation interference.

The observed parameters included plant height (cm), number of leaves, flowering time, number of flowers, number of flower pods, number of pods planted, pods weight per plant, the weight of 100 seeds/plant, fresh weight 5 and 8 WAP, dry weight 5 and 8 WAP, number of nodules, leaf area, root length, and leaf area index (LAI).

Data analysis used the F test at the 5% level. It continued with the randomized completely block design (RCBD) test at the 5% level if there was a significant influence of the treatment factor given to the observed characters. The data were subjected to analysis of variance; then, means were compared using Duncan's Multiple Range Test (DMRT). All tests were considered significant at $p < 0.05$. The data was processed using the Minitab and Microsoft Excel version 2021 software.

RESULTS AND DISCUSSION

Vegetative characters

Irrigation volume levels and varieties significantly interacted with plant height at 1-3 WAP but not at 4 and 5 WAP (Table 1). This is presumably because cowpea requires a lot of water in the vegetative phase. The results of the analysis of variance showed that the varietal treatment had a significant effect on plant height. The highest plant height was found in the Albina variety, 178.68 cm, compared to the Uno variety, 148.81 cm at 5 WAP. Plants that experience water shortages are generally smaller than plants that grow normally. Lack of water causes a significant decrease in yield and even causes plant death (Pantilu et al., 2012). In the vegetative phase, cowpea plants form tendrils, increasing plant height (Hendriyani et al., 2018). In the present experiment, plant height at 1-5 WAP was strongly affected by the volume of irrigation water. Irrigation volume 3xEo produced higher plants than other irrigation volumes every week. (Table 1). Higher water use efficiency was obtained in irrigation of 3x Eo; this irrigation level seems sufficient to meet the water needs of cowpea plants.

Table 1. Plants height of cowpea variety and irrigation volume at 1-5 WAP.

Treatment	Plant height (cm)				
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
Variety					
Albina	21.71a	67.54a	87.26a	121.75a	178.68a
Uno	21.39a	62.67b	85.34a	114.87b	148.81b
Irrigation volume					
0.75 Eo	19.93b	44.53d	74.18b	111.71b	149.15b
1.5 Eo	20.03b	56.59c	78.31b	111.96b	148.78b
2.25 Eo	23.50a	76.31b	94.09a	124.68a	176.56a
3 Eo	22.75a	83.00a	98.62a	124.87a	180.50a
Interaction	*	**	*	ns	ns

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

The administration of sorbitol osmolyte concentrations at the intensity of drought stress at different stages showed a significant effect on the parameter of observing plant height at 3 WAP, whereas for 4-6 WAP, the treatment did not affect plant height parameters (Suhartono et al., 2020). Sulistyono and Juliana (2016) state that the highest plant height is produced by irrigation every 2 days until 100% water is available (100% AT) from planting to harvest in cancer plants. Fauziah et al. (2016) reported that applying 100% ETc or conventional water increases plant height and the number of fresh leaves.

The interaction between varieties and irrigation volume affected the number of leaves at 1 to 5 WAP (Table 2.) This means that the response of the number of leaves to the irrigation volume of the Albina variety was different compared to that of the Uno variety. For the Albina variety, the response was $Y = 0.3333x + 3.1875$ ($R^2 = 0.8$), $Y = -0.1667x^2 + 1.375x + 3.5313$ ($R^2 = 0.7681$), $Y = -0.1667x^2 + 1.375x + 3.5313$ ($R^2 = 0.7681$), $Y = 0.2222x^2 + 0.5167x + 7.875$ ($R^2 = 0.9535$), and $Y = -2.3333x^2 + 9.7833x + 5$ ($R^2 = 0.7441$) at 1, 2, 3, 4, and 5 WAP respectively. For the Uno variety, the response was $Y = -0.1944x^2 + 1, 1542x + 2.7969$ ($R^2 = 0.9968$), $Y = -0.037x^2 + 0.9722x + 2$ ($R^2 = 0.9337$), $Y = -0.0185x^2 + 0.9083x + 2.0313$ ($R^2 = 0.925$), $Y = -0.0185x^2 + 0.9083x + 2.0313$ ($R^2 = 0.925$) and $Y = -2.2222x^2 + 9.3333x + 6.75$ ($R^2 = 0.3118$) at age 1, 2, 3, 4, and 5 WAP, respectively. Based on this response pattern, it can be seen that the optimum irrigation volume for the

Albina variety was 2.91 Eo, 3.0 Eo, 3.0 Eo, 3.0 Eo, and 2.11 Eo, while for the Uno variety, it was 3.0 Eo, 3.0 Eo, 3.0 Eo, 2.94 Eo, and 2.10 Eo, at 1,2,3,4, and 5 WAP, respectively.

The number of leaves increased with more irrigation volume provided, although at an irrigation level of 2.25 Eo, the number of leaves was not statistically significantly different from plants that received an irrigation volume of 3 Eo (Table 2). The Uno variety produced a higher number of leaves in the fast vegetative phase compared to the Albina variety, but at the approaching flowering phase (5 WAP) both varieties produced about the same number of leaves. Based on previous research by El Balla *et al.* (2013), water stress could reduce the number of leaves on shallot plants. It is likely that the decreasing number of leaves in the present research could be due to increasing water stress.

Davatgar et al. (2009) reported that drought in the vegetative phase inhibited plant height growth and the development of the number of tillers and leaves of rice plants. Subantoro (2014) water stress on peanut plants causes a decrease in photosynthetic activity. Three mechanisms cause water stress to reduce photosynthesis: a decrease in photosynthetic surface area, closure of stomata, and reduced activity of dehydrated protoplasm.

Table 2. Number of leaves in cowpea at 1-5 WAP from interaction treatment between varieties and irrigation volume.

Treatment	Number of leaves				
	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP
Variety Albina					
0.75 Eo	3.50d	4.62c	6.12cd	8.50b	11.43e
1.5 Eo	3.50d	4.75c	6.12cd	8.81b	13.18cd
2.25 Eo	4.12bc	6.25a	6.75a	10.50a	16.43b
3 Eo	4.12bc	6.00a	6.62ab	11.31a	12.93cde
R^2	0.8	0.7681	0.7681	0.9535	0.7441
Variety Uno					
0.75 Eo	3.56d	5.50b	6.37bc	9.00b	11.50de
1.5 Eo	4.06c	6.06a	6.05d	11.50a	18.75a
2.25 Eo	4.43ab	5.87ab	6.56ab	10.25ab	13.50c
3 Eo	4.50a	6.00ab	6.75a	11.81a	15.75b
R^2	0.9968	0.9337	0.925	0.5655	0.3118

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

Reproductive characters

Varieties and volume of irrigation affected nodule number, leaf area, root length, and LAI at 8 WAP but did not affect nodule number, leaf area, root length, and LAI at 5 WAP (Table 3). The interaction between varieties and irrigation volume affects the number of nodules, leaf area, root length, and LAI at the end of harvest. The highest number of nodules was produced on the uno variety and significantly differed from the Albina variety, reaching 48.56 at 5 WAP. Using irrigation volume, 3 Eo resulted in more nodules than other irrigation volumes for each parameter (Table 3).

Drought conditions can quickly reduce the viability of Rhizobium; this can also be exacerbated by wetting and drying cycles. These conditions can inhibit the formation of root nodules due to the failure of bacterial infection in the roots for the formation of root nodules (Suryantini, 2015). Rhizobium viability decreases rapidly under drought conditions, which is exacerbated by wetting and drying cycles. Drought reduces the amount of Rhizobium in the soil and inhibits knotting and nitrogen fixation. Effective root nodules can fix nitrogen and meet nitrogen requirements of 80-90% for plant growth. Lack of water or drought will result in plant dehydration, affecting cell turgor and further inhibiting plant growth (Sadmaka et al., 2017).

Table 3. Number of root nodules, leaf area, root length, and LAI of cowpea plants on variety treatment and irrigation volume.

Treatment	Number of nodules		Leaf area (cm²)		Root length (cm)		LAI	
	5 WAP	8 WAP	5 WAP	8 WAP	5 WAP	8 WAP	5 WAP	8 WAP
Variety								
Albina	31.75b	145.12a	41.76a	66.92a	23.00b	57.93a	0.013a	0.021a
Uno	48.56a	136.12b	40.46a	62.71b	31.62a	49.25b	0.013a	0.020a
Irrigation volume								
0.75 Eo	25.87b	219.25a	31.59c	48.24c	26.87	40.75b	0.010c	0.015c
1.5 Eo	26.00b	154.50b	37.63b	63.37b	27.25	51.50a	0.012b	0.020b
2.25 Eo	47.25ab	85.50c	46.22a	73.95a	30.75	61.25a	0.014a	0.023a
3 Eo	61.50a	103.25bc	49.00a	73.71a	24.37	60.87a	0.015a	0.023a
Interaction	ns	**	ns	**	ns	*	ns	**

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

The highest leaf area in the Albina variety was significantly different from the Uno variety, with the number of nodules reaching 48.56. The 3 Eo irrigation volume resulted in a higher leaf area than the other irrigation volumes (Table 3). The result is in line with a study by Suryaningrum et al. (2016) who stated that the leaf area index decreases with the high level of water stress and increasing plant age. Drought stress treatment significantly affected the total soybean leaf area, whereas, for each variety, it did not show a difference in response (Simanjuntak et al., 2015). The availability of water in green bean plants affects physiological and metabolic processes in plants. The effect of water stress on plant growth results in smaller leaf sizes (Felania, 2017).

Varieties do not affect the leaf area index (LAI) (Table 3). The highest LAI was produced in the Albina variety and was not significantly different from the uno variety. Increasing the irrigation volume level to 3 Eo markedly increased the LAI of plants at 8 WAP compared to other irrigation volumes. Similar to the leaf area, the leaf area index decreased with higher drought stress (Suryaningrum et al., 2016). Irrigation volume of 2.25 Eo resulted in higher root length at 8 WAP of 61.25 pods but was not significantly different from the administration of a lower irrigation volume of 0.75 Eo, and 1.50 Eo (Table 4). Root length is one of the morphological characteristics reported to be related to plant resistance to drought. Root length describes the ability of plants to obtain water supplies, including nutrient elements, in deeper soil layers (Torey et al., 2014).

Table 4. Interaction of variety and water volume on number of nodules 8 WAP, leaf area 8 WAP, root length, LAI 8 WAP, number of flowers 5 WAP, and number of pods set 5 WAP.

Treatment	Interaction of varieties and irrigation volume					
	Number of nodules at 8 WAP	Leaf area at 8 WAP (cm²)	Root length at 8 WAP (cm)	LAI at 8 WAP	Number of flowers at 5 WAP	Number pod set at 5 WAP#
Albina						
0.75 Eo	292.5a	61.25b	39.25c	0.0197b	34.58b	15.25c
1.5 Eo	59.0cd	59.15b	52.25bc	0.0190b	34.45b	20.00b
2.25 Eo	74.5cd	80.86a	71.25a	0.0260a	36.75a	22.00ab
3 Eo	154.5bc	66.44ab	69.00ab	0.0213ab	36.33ab	20.75b
Uno						
0.75 Eo	146.0cd	35.22c	42.25c	0.0108c	34.41b	14.75c
1.5 Eo	250.0ab	67.59ab	50.75c	0.0217ab	34.70b	21.75b
2.25 Eo	74.5cd	67.05ab	51.25	0.0215ab	37.66a	25.25a
3 Eo	52.0d	80.98a	52.75bc	0.0260a	36.83a	21.50b

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.
#Pod set: flower produces pod

Water stress conditions significantly affect plant performance (Moctava et al., 2013). Drought stress is the influence of environmental factors that cause water to be unavailable to plants, which can be caused, among other things, by the unavailability of water in plant root areas and large water demand in leaf areas, where the rate of evaporation exceeds the rate of water absorption by the roots. Associated with the humidity level of the media in the pot. Small pots will have a lower humidity level when compared to the media in large pots. Large pots have advantages in the growth of plant roots. The available space can provide enough space for the roots to breathe (Yuniarsih, 2017).

The type of variety and volume of irrigation affected the number of flowers and those that became pods at 5 and 7 WAP (Table 5). The interaction between varieties and irrigation volume affects the number of flowers and those that become pods at the beginning of flowering. The highest number of flowers and the number of flowers that became pods were produced in the Albina variety treatment. They were not significantly different from the other varieties, with the number of flowers reaching 14.56 and the number of flowers that became pods reaching 20.66 and 14.66, respectively (Table 5).

The irrigation volume of 2.25 Eo produced a higher number of flowers at 16.25 and 11.25, and the highest number of flowers that became pods were 24.58 and 18.58 compared to other irrigation volume treatments at 5 and 7 WAP, respectively (Table 5). This is presumably because the plants during the early flowering period need more water than those during the late. The greater the number of flowers, the higher the seed weight produced per plant (Fadillah et al., 2020). The research results on 20 varieties of soybean plants showed that the number of flowers correlated with the number of filled pods produced per plant and the number of pods correlated with seed weight per plant (Suyamto & Musalamah, 2016).

Table 5. Number of flowers and pod set of cowpea plants in the variety treatment and irrigation volume.

Treatment	Number of flowers		Number pod set#	
	5 WAP	7 WAP	5 WAP	7 WAP
Variety				
Albina	14.56a	20.66b	9.56a	14.66b
Uno	14.50a	24.79a	9.50a	18.79a
Irrigation volume				
0.75 Eo	12.62c	18.83b	7.62c	12.83b
1.5 Eo	13.50bc	23.08a	8.50bc	17.08a
2.25 Eo	16.25a	24.58a	11.25a	18.58a
3 Eo	15.75ab	24.41a	10.75ab	18.41a
Interaction	**	ns	**	ns

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%. #Pod set: flower produces pod

The level of irrigation volume and variety had a significant interaction effect on the dry weight of leaves at 5 WAP and the dry weight of leaves, stems, and roots at 8 WAP (Table 6) but did not have a significant interaction effect on the dry weight of stems and roots at 5 WAP. Mahdalena (2020) found that water stress significantly affected the upper plants' dry weight at 7 WAP and at harvest.

Plant dry weight is closely related to the decrease in the rate of photosynthesis. The high level of drought disturbs nutrient uptake and stunted growth, that is indicated by the reduced plant dry weight (Hidayati et al., 2017). The decrease in dry canopy weight was caused by the inhibition of water and nutrient absorption due to the increased osmotic pressure of the solution in the soil, so the process of photosynthesis was disrupted (Wahyuningsih et al., 2017).

Irrigation volume significantly affected the weight of cowpea roots. The lowest average root weight was found in the irrigation treatment of 0.75 Eo, while the highest average root weight was in the irrigation treatment of 3 Eo. This follows the results of research (Wullschleger et al., 2005) that the root volume of plants affected by drought stress has a lower root volume due to limited turgor pressure.

Table 6. Dry weight of cowpea at 5 and 8 WAP on variety treatment and irrigation volume.

Treatment	Plant dry weight 5 WAP			Plant dry weight 8 WAP		
	Leaf	Stem	Root	Leaf	Stem	Root
Variety						
Albina	1.83b	2.72a	0.25b	9.34a	13.03a	1.38a
Uno	2.05a	2.46b	0.32a	9.25a	11.58a	0.99b
Irrigation volume						
0.75 Eo	1.76b	2.25d	0.22c	6.54b	9.30b	1.12a
1.5 Eo	1.81b	2.61c	0.26b	9.29ab	12.10ab	1.13a
2.25 Eo	2.17a	3.06b	0.29ab	10.86a	13.63a	1.24b
3 Eo	2.33a	3.45a	0.31a	10.49a	14.19a	1.27b
Interaction	**	ns	ns	*	**	**

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

The interaction between varieties and irrigation volume affected the dry weight of plant shoots at 8 WAP (Table 7). This means that the pattern of response of shoot dry weight to variety depends on the volume of irrigation used. Suppose it is depicted in the form of a quadratic equation curve (Figure 2), then the response pattern of shoot dry weight (y curve) to irrigation volume (x) is obtained in the albina variety treatment which has an equivalent value y = -1.1358x2 + 3.7553x + 3.9014 and y = -1.229x2 + 4.3944x + 2.2174 for the Uno variety. Based on the quadratic equation, it was formulated that the optimum irrigation volume for the Albina variety was 1.66 Eo, and for the Uno variety, it was 1.79 Eo at 8 WAP or in the generative phase of the plant.

Table 7. Dry weight interaction of cowpea plants at 8 WAP on varietal treatment and irrigation volume.

Irrigation volume	Cowpea variety	
	Albina	Uno
0.75 Eo	5.92c	5.39c
1.5 Eo	7.31bc	7.70abc
2.25 Eo	10.61a	6.54bc
3 Eo	7.83abc	9.46ab
R^2	0.6748	0.7468

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

Plant dry weight is closely related to a decrease in photosynthesis rate. High levels of drought cause the absorption of nutrients and the water supply needed for growth to be inadequate, so generative growth is hampered and this is indicated by a reduction in plant dry weight (Hidayati et al., 2017). The 2.25 Eo treatment on the Albina variety is better than the 0.75 treatment and the 3.00 Eo treatment is better than 2.25 Eo on the Uno variety. It is suspected that the Albina variety is more resistant to drought than the Uno variety.

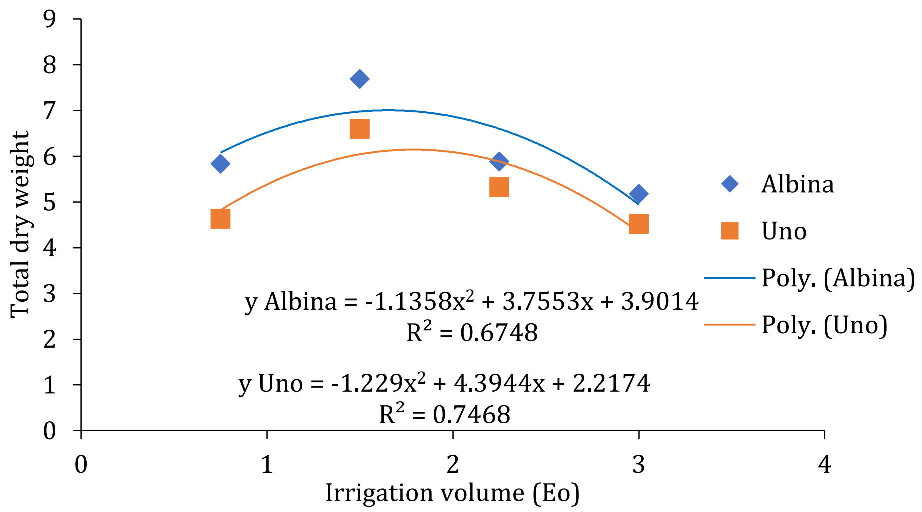

Figure 2. Response patterns of the total dry weight of two cowpea varieties to the irrigation volume.

The interaction of the level of irrigation volume and variety was significant on the fresh weight of leaves and stems at 5 and 8 WAP and the root fresh weight at 8 WAP (Table 8). Root fresh weight at 5 WAP significantly affected each treatment but did not significantly affect the interaction. The results showed that the volume of irrigation affected the fresh weight of leaves and stems at 5 WAP and the fresh weight of leaves, stems, and roots at 8 WAP. Giving irrigation volumes higher up to 3.0 Eo resulted in the highest average of the observed variables. Table 7 shows that the irrigation volume treatment did not affect the fresh leaf and stem weights. There are differences between varieties on the fresh weight of the leaves. The Albina variety produced a higher leaf fresh weight compared to Uno.

Table 8. Fresh weight of cowpea plants aged 5 and 8 WAP on variety treatment and irrigation volume.

Treatment	Plant fresh weight 5 WAP			Plant fresh weight 8 WAP		
	Leaf	Stem	Root	Leaf	Stem	Root
Variety						
Albina	14.82b	19.09b	2.06b	57.73b	76.86b	9.28a
Uno	13.80a	17.16a	2.47a	55.82a	78.73a	7.97b
Irrigation volume						
0.75 Eo	12.85b	16.29b	2.03b	49.88c	64.80d	9.12a
1.5 Eo	14.34b	17.85b	2.02b	54.23bc	73.75c	8.72a
2.25 Eo	14.08a	18.14a	2.48a	62.45ab	81.73b	8.62ab
3 Eo	15.96a	20.22a	2.53a	60.53a	90.90a	8.05b
Interaction	*	*	ns	*	*	**

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at α = 5%.

Leaf fresh weight results from metabolic activity and photosynthate accumulation in biomass during growth. Which can be characterized by weight gain. Leaf fresh weight can reflect the physiological functions of leaves related to photosynthesis and respiration (Huang et al., 2019).

Yield and yield component

The analysis of variance showed that variety had a very significant effect on the number of pods per plant, flowering age, and fresh pod weight per plant but had no significant effect on the weight of 100 grains. The number of pods for the uno variety was higher than the albina variety, which was 20.81, compared to the Albina variety, which was 19.50. The weight of 100 grains of the Albina variety was higher than the uno variety, which was 16.42g, compared to the uno variety, which was 15.41g. This is presumably because the seed size of the Albina variety is larger than the seed size of the Uno variety. The average pod weight per plant in the albina variety was 48.13 g, while in the uno variety, it was 45.03. This is presumably because the size of the Albina pods is larger than the Uno.

The study results from Rabani et al. (2022) showed that variety affected pod length, number of pods, fresh pod weight per plant, dry pod weight per plant, tiled pod weight, dry seed weight, and productivity at plant age 9 WAP. The analysis of variance showed that irrigation volume had a very significant effect on the number of pods per plant, flowering age, fresh pod weight per plant, and seed production weight per plant but had no significant effect on the weight of 100 grains. Treatment of the higher irrigation volume will produce higher yields on the observed variables (Table 9).

Table 9. Number of pods per plant, flowering age, weight of 100-grain weight, pod weight per plant, and seed weight per plant of cowpea on varietal treatment and irrigation volume.

Treatment	Number of pods per plant	Flowering age (DAP)	Weight of 100 grains (g)	Pod weight per plant (g)	Seed weight per plant (g)
Variety					
Albina	19.50a	35.53a	16.42a	48.13a	34.20
Uno	20.81b	35.90a	15.41b	45.03b	34.30
Irrigation volume					
0.75 Eo	15.00c	34.50b	16.03b	40.03c	25.08c
1.5 Eo	20.87b	34.58b	15.98a	41.11c	35.86b
2.25 Eo	23.62a	37.20a	15.81a	55.09a	40.54a
3 Eo	21.12b	36.58a	15.84a	50.07b	35.52b
Interaction	ns	ns	ns	ns	ns

Note: Numbers followed by the same letter in the same column are not significantly different based on the DMRT test at $\alpha = 5\%$.

The plants respond positively to irrigation but do well in dryland conditions. The effect of drought stress on cowpea yield depends on the genotype, intensity of water stress, duration, and growth stage exposed to water stress. Cowpea yields are significantly affected by water stress and produce high yields by supplementing crop water needs through irrigation (Dadson et al., 2005).

The age at which plants start to flower is significantly affected by the volume of irrigation. The fastest average age of plants starting to flower was obtained in the irrigation volume treatment of 0.75 Eo at DAP 34.58 (Table 9). DAP and the age of the plants starting to flower late in the 3 Eo treatment, namely at 37.20; this is following research Monggesang & Pinaria (2022) which shows the flowering age of the Anjasmoro soybean variety is faster, namely 37 HST. The plant will promptly undergo its life cycle if in a water stress condition. Dadson et al. (2005) Several genotypes of cowpeas that experienced water stress experienced flowering 2-4 days faster than plants without water stress.

The first harvest was carried out on plants aged 55 days after planting. The pods were harvested at intervals of 5 days for each harvest period. Early harvesting is suspected to be due to the influence of irrigation volume on cowpea, this is not following the results of research by Fadillah et al. (2020) that cowpeas are harvested at the age of 59-81 days after planting.

The interaction between varieties and irrigation volume did not affect the weight of seed production per plant (Figure 3). This means that the response of the weight of seed production per plant to the irrigation volume of the two varieties was the same, Y = -7.025x2 + 31.143x + 5.4966 (R^2 = 0.9555). Based on the quadratic equation, it can be seen that the optimum irrigation volume for two varieties is 2.22 Eo.

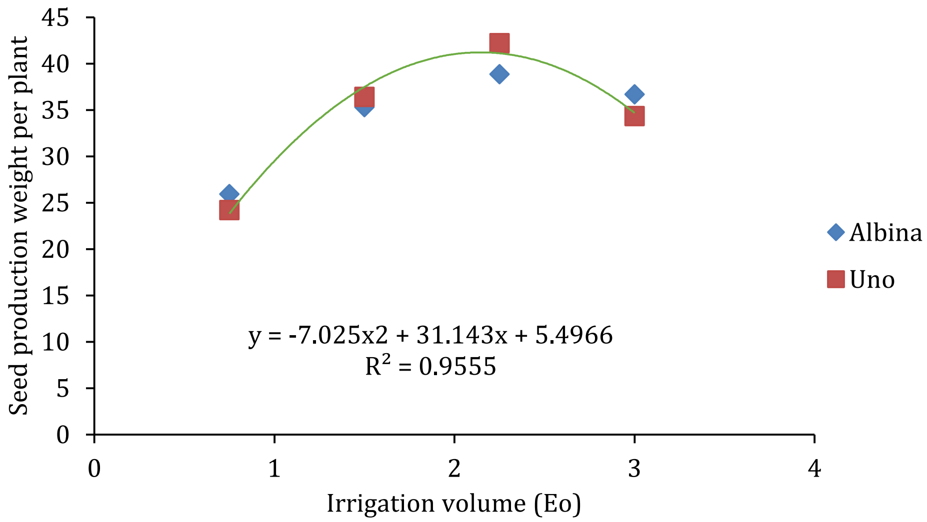

Figure 3. The average response pattern of the seed weight per plant to the irrigation volume of the two cowpea varieties.

The analysis of variance showed that the irrigation volume treatment had a very significant effect on the variable weight of seed production per plant (Table 9). The lowest seed production weight per plant was obtained in the 0.75 Eo treatment of 25.08 and the highest in the 2.25 Eo treatment of 40.54. This is consistent with the results of a study by Suhartono et al. (2020), which showed a significant effect due to the interaction between several concentrations of sorbitol osmolytes and different intensities of drought stress on the average number of entire pods, total number of pods and dry weight of pods per plant.

Drought stress causes flower drop, pod drop, and pod burst. The more flowers that fall and the pods fall and break, causing a significant decrease in the number of pods/plants (Sehrawat et al., 2013). The amount of irrigation water given to plants will determine the yield factor for plants because the amount of irrigation water determines the value of ETc (Setiawan et al., 2014).

CONCLUSIONS

Irrigation volume and type of varieties affect plant height, number of leaves, dry weight, fresh weight, number of pods per plant, pod weight per plant, flowering age, 100-grain weight, seed production weight per plant, number of nodules, root length, leaf area, LAI, the number of flowers and the number of pod set. The water requirement of the plant during the vegetative phase based on plant height and number of leaves at 1, 2, 3, 4, and 5 WAP for the Albina variety was 2.91 Eo, 3.0 Eo, 3.0 Eo, 3.0 Eo, and 2.11 Eo, while for the Uno variety was 3.0 Eo, 3.0 Eo, 3.0 Eo, 2.94 Eo, and 2.10 Eo, respectively. The water requirement of the plant during the generative phase based on dry weight for the Albina variety was 1.66 Eo, and for the Uno variety was 1.79 Eo. The combination of 2.25 Eo irrigation volume with the Uno variety produced the highest grain production per plant and was significantly different from other irrigation volumes. The combination of irrigation volume of 2.25 Eo with the Albina variety was chosen as the best treatment for water use efficiency during vegetative and generative growth of cowpea; while the Uno variety exhibited superiority in low water use at the reproductive phase.

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