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Effects of Fertilization Ratios on the Growth of Pinto Peanut (*Arachis pintoi*) under Drought Stress Conditions

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Abstract

The objectives of this study were to evaluate the effects of different fertilization ratios on the growth of pinto peanut (*Arachis pintoi*) propagated vegetatively under varying water regimes. The experiment was carried out in a net-house in a completely randomized design with three replicates. The $N:P_2O_5:K_2O$ ratios were applied at six levels: F1 (1:1:1), F2 (1:3:1), F3 (1:1:3), F4 (3:1:1), F5 (3:3:1), and F6 (3:3:3) while soil moisture included three different levels: 30% (W1), 60% (W2), and 100% (W3) field capacity. Water stress conditions were treated from 30-65 days after planting, and then the pots were irrigated to 100% field capacity. The results indicate that drought conditions significantly reduced ($P<0.05$) the growth of stolons, leaf appearance, number of secondary stolons, and dry matter, while the root/shoot ratio was higher compared to plants under well-watered conditions. There was no significant effect of the fertilization ratios on the number of secondary stolons. Higher-NP and NPK application ratios showed significant influences on the growth of *A. pintoi* under drought conditions by stimulating stolon lengths and the number of leaves, while the root/shoot ratio was decreased. Higher ratios of single fertilizers (N, P, or K) did not show a consistent effect on the growth of *A. pintoi* under drought conditions. The results suggest that a higher-NP fertilization ratio stimulates the growth of *A. pintoi* under both drought and well-irrigated conditions.

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Keywords

Water stress, fertilization, cover crops

Introduction

Arachis pintoi is a leguminous plant valued in many tropical regions due to its adaptability, biomass production, nitrogen fixation, and soil coverage. *A. pintoi* can reduce soil erosion and maintain soil moisture due to its deep roots and high canopy coverage. Studies conducted in Nigeria demonstrated that *A. pintoi* reduced soil water evaporation by 41.1%, providing conservation of soil moisture for succeeding crops (Oluwasemire and Fademi, 2013). Also, the capability of *A. pintoi* to fix atmospheric nitrogen improves soil fertility. Ngome and Mtei (2010), in an experiment on *A. pintoi* (CIAT 18744) at 5 different sites in western Kenya, reported that nitrogen fixation ranged from 23 to 46 kg ha^{-1} N, and there was a significant positive correlation between dry matter production and nitrogen fixation.

Moreover, *A. pintoi* is also grown for fodder, though yield varies among accessions, soil fertility, and climate. Carvalho and Quesenberry (2012) estimated that *A. pintoi* has excellent nutritive value for livestock with high crude protein content and a high in vitro organic matter digestibility. In an experiment carried out in Florida, U.S.A. in 2003, Carvalho and Quesenberry (2012) reported that the mean dry forage yield of 24 accessions of *A. pintoi* was 4.3 tons ha^{-1} and ranged from 0 to 9.1 tons ha^{-1}. In another experiment with the accession CIAT 17434, Argel (1994) indicated that forage dry matter yield 16 weeks after planting was 2.1 tons ha^{-1}. In Bolivia, Brazil, Ecuador, Colombia, and Peru, the dry matter yields of accession CIAT 17434 12 weeks after planting were between 0 and 2.7 tons ha^{-1} in the rainy season, and 0.04 to 2.8 tons ha^{1} in the dry season (Pizarro and Rincón, 1994).

However, one of the main limitations of *A. pintoi* is its very low establishment rate, depending on the soil fertility, water regime, and planting density (Ramos *et al*., 2010). According to Sales *et al.* (2012), nitrogen fertilization is an efficient practice to accelerate the establishment of *A. pintoi* by stimulating the growth of leaves and stolons. Pizarro and Rincón (1994) reported that *A. pintoi* had a wide range of adaptability; however, its maximum growth was observed under humid tropical conditions with an average annual rainfall ranging from 2000 to 4000 mm.

Past studies confirmed the effects of the water regime and fertilizer on the growth and biomass yield of *A. pintoi,* mainly considering the effect of nitrogen fertilization. However, the synergic effects of nitrogen, phosphate, and potassium on growth under varying water regimes have yet to be investigated. To address this knowledge gap, the present study was designed to evaluate the effects of different fertilization ratios under varying soil water regimes on the growth of *A. pintoi* vegetatively propagated.

Materials and Methods

The experiment was conducted in a net-house at the Faculty of Agronomy, Vietnam National University of Agriculture (VNUA), Vietnam. Free-draining pots (28 cm in diameter, 25 cm in depth) were filled with 6 kg of air-dried soil. The soil was collected at a depth of 0-20 cm from the research field at VNUA. The soil was air-dried and then sieved before filling the pots. The soil was slightly acidic (pH = 5.96), containing 0.6% of organic matter, was rich in available nitrogen (6.44 mg N/100 g soil) and available phosphorus (59.69 mg P_2O_5/100 g soil), and moderately-rich in available potassium (18.02 mg K_2O/100 g soil).

A 3 x 6 factorial arrangement was used, the main effects being the water regime and the N:P:K ratio. In the experiment, N:P_2O_5:K_2O ratios were applied at six levels: F1 (1:1:1), F2 (1:3:1), F3 (1:1:3), F4 (3:1:1), F5 (3:3:1), and F6 (3:3:3), with 1 N considered to be equivalent to 0.1 g N kg^{-1} soil. Phosphate was applied on the day of planting. Nitrogen and potassium were divided into two applications: the first on the day of planting and the second at 25 days after planting (DAP). Water regimes were applied with three irrigation levels: W1 - 30% (severe drought stress), W2 - 60% (mild drought stress), and W3 - 100% of field capacity (FC) (well-watered conditions). During the first 30 days of the experiment, all pots were watered daily to maintain a water regime close to 100% of FC. At 30 DAP, plants in the W1 and W2 treatments were not watered until the water regimes reached 60% of FC in treatment W2 and 30% of FC in treatment W1. Afterward, the water stress was maintained until 65 DAP by weighing each pot daily before watering. Soon after the water-stress period (at 66 DAP), the W1 and W2 treatments were irrigated again to maintain water regimes close to 100% of FC.

For determination of field capacity, five pots containing dry soil were weighed, saturated with water, and, after the water began flowing from the bottom of the pot, weighed again. The difference between the wet and dry weights indicated the maximum water holding capacity.

The experiment was arranged in a completely randomized design with three replicates. There were 9 pots per treatment, totalling 54 pots. The *A. pintoi* accession was collected in Gialam, Hanoi, Vietnam. The plant seedlings were grown from stolon pieces containing 4 nodes from mother plants. After shoot development, 6 plants were maintained per pot.

Agronomic traits including the number of leaves, stolon length, and secondary stolons were measured weekly. The soil and plant analyzer development (SPAD) index of leaves was measured by a SPAD meter (SPAD-502, Japan) at 9, 12, and 15 weeks after planting (WAP). At the same time, one plant from each treatment was randomly harvested and then the stem and roots were separately oven-dried at 80°C for 48 hours for determination of dry matter.

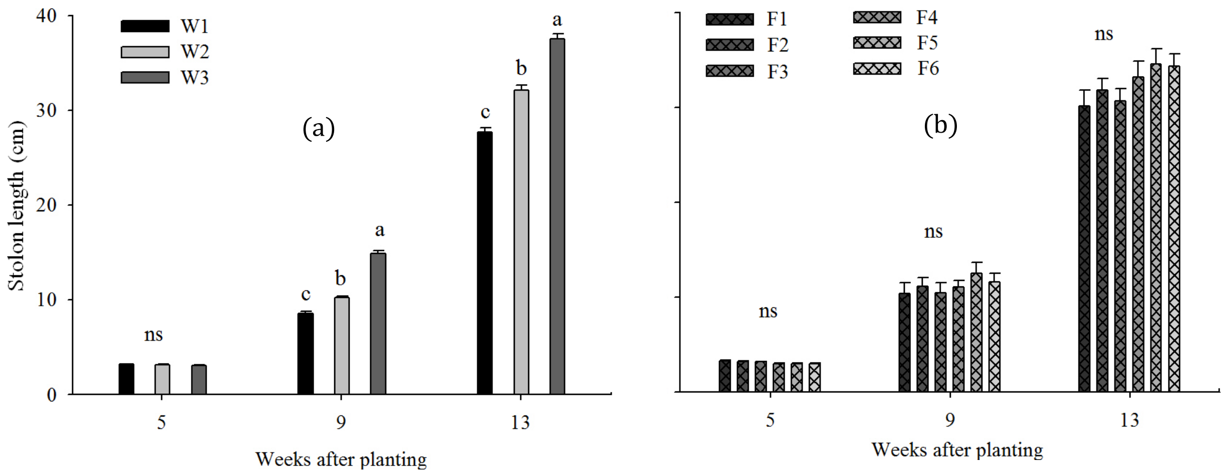
The data were analyzed using the analysis of variance (ANOVA) performed by the STATISTICA 6.0 software. The differences between treatments were determined using Tukey's HSD at $P<0.05$. The figures were prepared using SigmaPlot 10.0 software.

Results and Discussion

The effects of the fertilization ratios and water regimes on the stolon lengths of *A. pintoi*

It was observed that the water stress treatments significantly ($P<0.05$) inhibited the stolon lengths of *A. pintoi* (Figure 1). Both water stress treatments (W1 and W2) inhibited the stolon lengths at 9 and 13 WAP in comparison to the well-watered conditions (W3). The lowest stolon length was observed in the severe drought stress (W1) treatment. However, no effects of the fertilization ratios on the stolon lengths were detected.

The interactions among the water regimes and fertilization ratios on the stolon lengths of *A. pintoi* are shown in Table 1. At 5 WAP, there was no difference in the lengths of stolons among treatments. At 9 WAP, the higher N (F4), higher NP (F5), and higher NPK (F6) treatments had significantly longer stolon lengths compared with F1 under severe water stress (W1). Under mild water stress (W2), plants in the higher NP and higher NPK ratio



Note: (ns): not significant. Means accompanied by different letters are significantly different at the 5% level between treat ments in each week after planting. The error bars represent the standard errors (SE) of the means.

Figure 1. Effects of the water regimes (a) and fertilization ratios (b) on the stolon lengths of *A. pintoi*

treatments induced significantly longer stolon lengths in comparison to F1 at 9 WAP (P<0.05). Under well-watered conditions (W3), the greatest stolon length was recorded at the higher NP treatment, whereas there was no difference between other fertilizer treatments. At 13 WAP, the higher P, higher NP, and higher NPK treatments had significantly (P<0.05) longer stolon lengths under severe drought (W1) compared with F1. Under the W2 treatments, the higher N, higher NP, and higher NPK treatments resulted in longer stolon lengths compared to F1 and the higher K treatments. Under well-watered conditions (W3), the higher K (F3) treatment had slightly shorter stolon lengths compared to F1 while the highest stolon lengths were observed in the higher NP treatments.

Sales *et al.* (2012) indicated a linear response of the stolon elongation rate and a quadratic response of final stolon lengths of *A. pintoi* in relationship to the nitrogen rate. The greatest stolon lengths were observed at a dose equivalent to 86 kg ha^{-1} N. In our experiment, higher K alone did not affect the stolon lengths of *A. pintoi*. However, the results suggested that fertilizer treatments with high-N, high-NP, and high-NPK ratios may stimulate stolon elongation under water stress. A decrease of plant growth under drought stress may be partly explained by less water and less available nutrient uptake for cell division and enlargement (Aslam *et al.*, 2015). At the same fertilization ratios, the stolon lengths generally increased with higher water moisture levels, which implies that water regimes showed a greater impact on stolon lengths than the fertilization ratios alone.

Table 1. The interaction of water regimes and fertilization ratios on the stolon lengths of *A. pintoi*

Water regimes	Fertilizer ratios	Stolon length (cm)		
		5 WAP	9 WAP	13 WAP
W1	F1	3.3	7.1^{g}	25.3^{k}
	F2	3.4	8.6^{efg}	28.2^{ghi}
	F3	3.2	7.8^{fg}	26.1^{ik}
	F4	3.1	8.9^{def}	27.1^{hik}
	F5	3.2	9.6^{cde}	29.7^{fgh}
	F6	3.0	9.4^{def}	29.8^{fgh}
W2	F1	3.4	9.3^{def}	29.0^{fgh}
	F2	3.3	10.2^{cde}	31.4^{ef}
	F3	3.2	9.6^{cde}	30.5^{fg}
	F4	3.1	10.6^{cd}	33.5^{de}
	F5	2.9	11.1^{c}	33.6^{de}
	F6	2.9	10.4^{c}	34.6^{d}
W3	F1	3.2	14.5^{b}	36.2^{bc}
	F2	3.1	14.7^{b}	35.9^{cd}
	F3	3.2	14.4^{b}	35.3^{d}
	F4	2.9	13.7^{b}	38.8^{ab}
	F5	2.9	16.9^{a}	40.4^{a}
	F6	3.1	15.1^{b}	38.6^{abc}
ANOVA $_{(W\&F)}$		ns	*	*

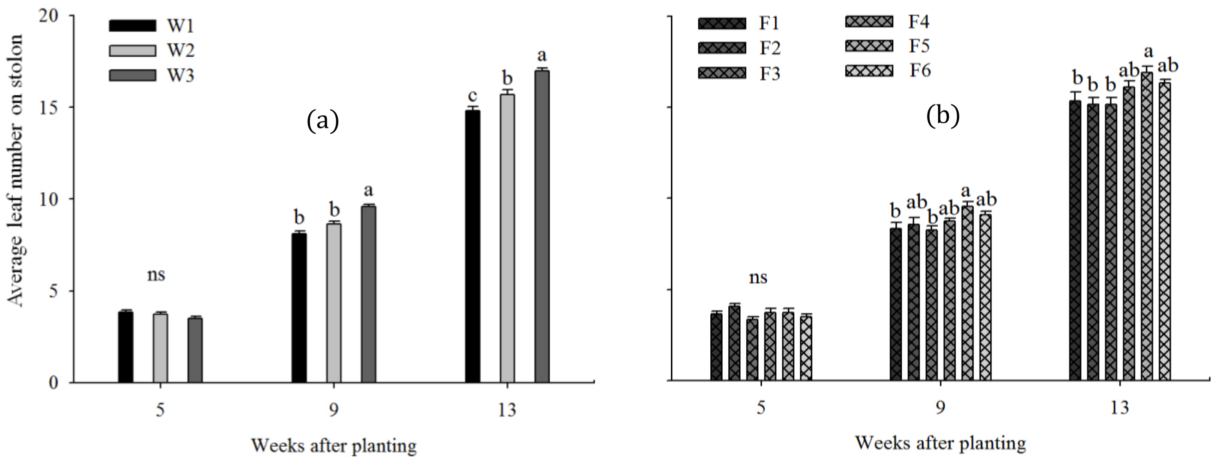
Note: (ns): not significant, (*): significant at the 5% level. Values followed by different letters within a column indicate significant differences at the 5% level.

The effects of fertilization ratios and water regimes on the number of leaves of *A. pintoi*

The effect of water regimes on the number of leaves on the primary stolon was found to be significant (Figure 2). Both water stress treatments (W1 and W2) significantly reduced (P<0.05) the number of leaves of *A. pintoi* at 9 WAP and 13 WAP in comparison to the well-watered condition (W3). At 13 WAP, plants under severe drought (W1) induced a lower number of leaves in comparison to the plants under mild drought (W2). A significant effect of the fertilization ratios on the number of leaves was observed at 9 WAP and 13 WAP (P<0.05). Whereby, the higher NP ratio treatment (F5) led to a higher number of leaves in comparison to the F1 and F3 treatments at 9 WAP, and to the F1, F2, and F3 treatments at 13 WAP.

At 5 WAP, there was no difference in the number of leaves among treatments. At 9 WAP, the higher NP treatments had a higher number of leaves under severe drought (W1), while the higher NP and higher NPK treatments resulted in a higher number of leaves under mild drought (W2) in comparison to F1. At 13 WAP, plants in the higher NP and higher NPK treatments induced significantly higher leaf numbers in comparison with F1 at both water stress conditions. However, under the well-watered conditions, there was no effect of the fertilization ratios on the number of leaves of *A. pintoi*. At the same fertilizer ratio, drought stress led to a lower number of leaves compared with well-watered, except in the higher NP and higher NPK treatments under mild drought (W2).

It has been shown that there is a quadratic response of the nitrogen fertilization level on the leaf appearance rate (Sales *et al.*, 2012). In another experiment, Sales *et al.* (2013) indicated a significant effect of water regimes and nitrogen application on the leaf growth and development of *A. pintoi*. The highest number of green leaves per pot was observed with an application rate of 80 kg ha^{-1} N under 80% FC. Higher water stress and lower N application reduced green leaf numbers. The highest leaf appearance rate was found at 120 kg ha^{-1} N and 90% FC; whereas the lowest leaf appearance rate was observed at the same N level and 25% FC. Sheng (2013) reported that drought stress inhibited the growth of the aerial parts of *A. pintoi*. Low water moisture may reduce nutrient diffusion (Waraich *et al.*, 2011), transpiration rate, and active transport (Hsiao, 1973; Kramer and Boyer, 1995), thus reducing nutrient uptake. In our experiment, we confirmed a significant impact of the water regimes on leaf appearance of *A. pintoi*. In addition, a positive effect of higher NP and higher NPK ratios on the number of leaves of the plants under water stress was also observed.



Note: (ns): not significant. Means accompanied by different letters are significantly different at the 5% level between treatments in each week after planting. The error bars represent the standard errors (SE) of the means.

Figure 2. Effects of water regimes (a) and fertilization ratios (b) on the number of leaves of *A. pintoi*

Table 2. The interactions of water regimes and fertilization ratios on number of leaves of *A. pintoi*

Water regimes	Fertilizer ratios	Average number of leaves on the stolon		
		5 WAP	9 WAP	13 WAP
W1	F1	3.4	7.5^{f}	14.1^{e}
	F2	4.1	8.0^{ef}	14.3^{de}
	F3	3.6	7.4^{f}	13.8^{e}
	F4	4.3	8.4^{cdef}	15.2^{cde}
	F5	3.9	8.9^{abcde}	15.7^{bc}
	F6	3.6	8.3^{cdef}	15.9^{cd}
W2	F1	4.1	7.9^{ef}	14.7^{de}
	F2	4.4	7.9^{ef}	14.5^{de}
	F3	3.2	8.3^{cdef}	15.2^{cde}
	F4	3.3	8.7^{bcdef}	15.8^{cd}
	F5	3.7	9.6^{abcd}	17.4^{ab}
	F6	3.5	9.3^{abcd}	16.4^{abc}
W3	F1	3.4	9.7^{abc}	17.3^{ab}
	F2	3.7	9.8^{ab}	16.7^{abc}
	F3	3.2	9.0^{abcde}	16.4^{ab}
	F4	3.6	9.2^{abcde}	17.3^{ab}
	F5	3.6	10.2^{a}	17.6^{a}
	F6	3.4	9.6^{abcd}	16.7^{abc}
ANOVA $_{(W\&F)}$		ns	*	*

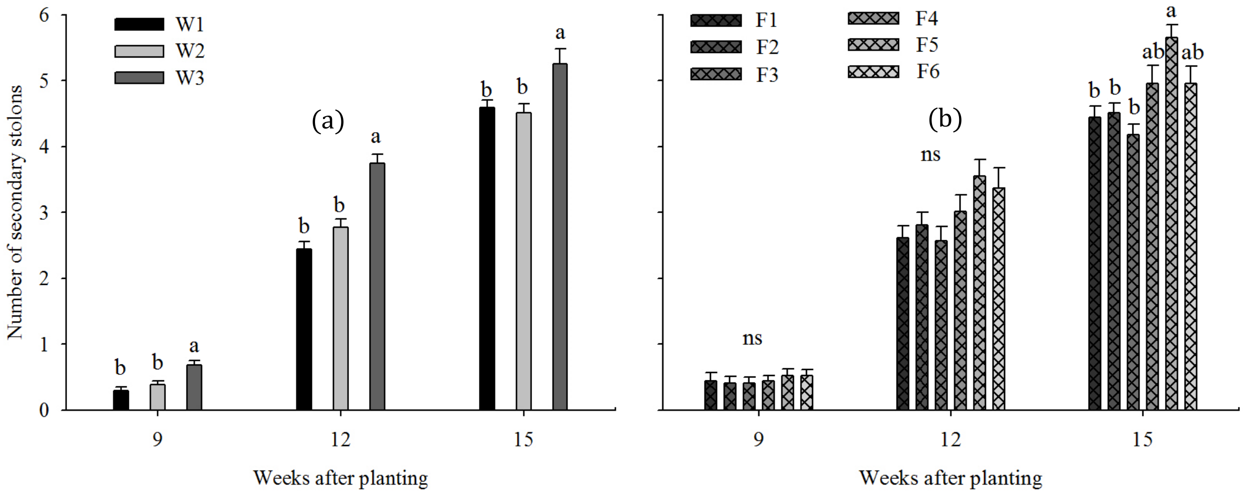
Note: (ns): not significant, (*): significant at the 5% level. Values followed by different letters within a column indicate significant differences at the 5% level.

The effects of the fertilization ratios and water regimes on the number of secondary stolons of *A. pintoi*

As shown in Figure 3, *A. pintoi* began producing secondary stolons at 9 WAP. However, the number of secondary stolons quickly increased after that. The number of secondary stolons of *A. pintoi* was significantly affected by the water stress conditions (P<0.05). Therefore, the W1 and W2 treatments led to a significantly lower number of secondary stolons in comparison to W3. The impact of the fertilizer ratio on secondary stolons was only observed at 15 WAP, in which plants under higher NP produced more secondary stolons than those in the F1, higher P (F2), and higher K (F3) treatments.

The data in Table 3 show the interactive effects of the water regimes and fertilization ratios on the number of secondary stolons of *A. pintoi*. Under higher water stress treatments (W1), there was no effect of the fertilization ratios on the number of secondary stolons. Under the mild drought (W2) and well-watered conditions (W3), a significant effect of the fertilizer ratio was found at 15 WAP, whereby higher NP (F5) increased the number of secondary stolons compared with F1. Even though the difference was not statistically significant, plants showed a tendency to produce more secondary stolons in the higher NP treatments in both water stress and well-watered conditions.

The growth of secondary stolons plays an important role in the speed of establishment of *A. pintoi* and consequently impacts soil coverage. Sales *et al.* (2012) indicated a linear increase in the number of secondary stolons of *A. pintoi* with increasing nitrogen fertilization rates. In our experiment, no significant effects of higher nitrogen ratios on the number of secondary stolons was observed, this could be attributed to high available nitrogen and phosphate in the experimental soil.



Note: (ns): not significant. Means accompanied by different letters are significantly different at the 5% level between treat ments in each week after planting. The error bars represent the standard errors (SE) of the means.

Figure 3. Effects of water regimes (a) and fertilizer ratios (b) on the number of secondary stolons of *A. pintoi*

Table 3. The interaction of water regimes and fertilizer ratios on the number of secondary stolons of *A. pintoi*

Water regimes	Fertilizer ratios	Number of secondary stolons		
		9 WAP	12 WAP	15 WAP
W1	F1	0.2	2.2[cd]	4.3[cd]
	F2	0.3	2.4[cd]	4.5[cd]
	F3	0.2	2.1[d]	4.0[d]
	F4	0.3	2.6[cd]	4.7[bcd]
	F5	0.3	2.9[bcd]	5.2[abc]
	F6	0.3	2.4[cd]	4.8[bcd]
W2	F1	0.6	2.5[cd]	4.1[d]
	F2	0.3	2.6[cd]	4.8[bcd]
	F3	0.3	2.3[cd]	4.2[cd]
	F4	0.4	2.6[cd]	4.3[cd]
	F5	0.3	3.4[abc]	5.4[abc]
	F6	0.3	3.4[abc]	4.3[cd]
W3	F1	0.6	3.2[abcd]	4.9[bcd]
	F2	0.6	3.4[abc]	4.2[cd]
	F3	0.7	3.3[abcd]	4.3[cd]
	F4	0.6	3.9[ab]	5.9[ab]
	F5	0.9	4.4[a]	6.3[a]
	F6	0.9	4.2[a]	5.9[ab]
ANOVA $_{(W\&F)}$		ns	*	*

Note: (ns): not significant, (*): significant at the 5% level. Values followed by different letters within a column indicate significant differences at the 5% level.

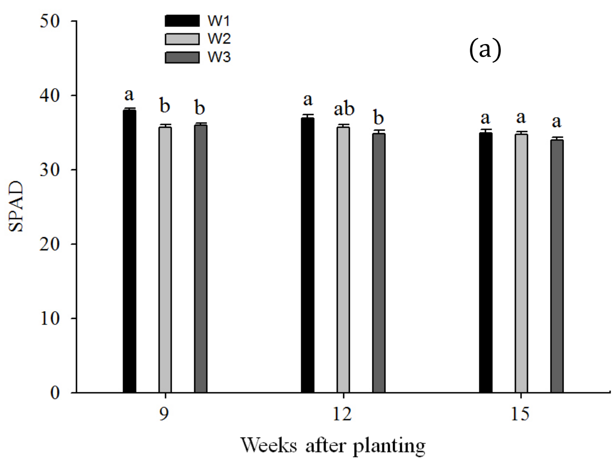
The effects of the fertilization ratios and water regimes on the SPAD index of *A. pintoi*

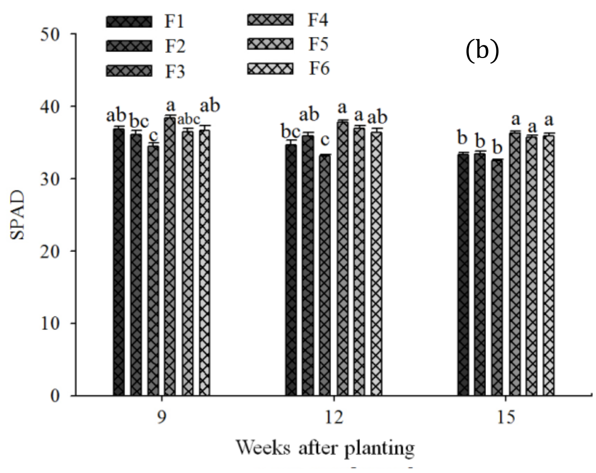
Figure 4 shows the effect of the water regimes and fertilization ratios on the SPAD readings of *A. pintoi*. At 9 WAP, the highest SPAD reading was found under higher water deficiency (W1), while there was no difference between the W2 and W3 treatments. At 12 WAP, a higher SPAD reading was observed under severe water stress (W1) compared with the well-watered conditions (W3). However, there was no effect of the water regimes on the SPAD readings at 15 WAP.

The effect of the fertilizer ratio on the SPAD readings of *A. pintoi* was significant at the three measured times. At 9 WAP, the higher K treatment (F3) led to a lower SPAD reading compared with the F1 treatment, higher N treatment (F2), and higher NPK treatment (F6). At 12 WAP, the higher N and higher NP treatments significantly increased (P<0.05) the SPAD readings in comparison to the F1 and higher K treatments (F3). At 15 WAP, plants under the three treatments with higher nitrogen ratios (N4, N5, and N6) induced higher SPAD readings in comparison to those in lower nitrogen ratio treatments (N1, N2, and N3). The interaction between the water regimes and fertilization ratios was significant for the SPAD measurements at 9 and 12 WAP (Table 4). Under the severe water stress condition (W1), plants in the higher N and higher NPK treatments showed higher SPAD readings at 9 WAP when compared with the higher K treatment. At 12 WAP, the lowest SPAD reading was observed under the higher K treatment (F3), whereas other fertilization ratio treatments significantly increased SPAD readings in comparison with F1.

Under the W2 treatment, the higher K fertilizer ratio (F3) led to lower SPAD readings in comparison to F1 at 9 and 12 WAP. Generally, the highest SPAD readings were observed in the higher N treatment (F4). Under well-watered conditions (W3), there was no effect of the fertilizer ratio on the SPAD readings at 9 WAP. However, treatments with higher N and/or higher P ratios enhanced the SPAD readings of *A. pintoi* at 12 WAP in comparison to the F1 and higher K treatments (F3). The interaction effect of the water regimes and fertilization ratios on the SPAD readings was not significant at 15 WAP.

Sheng (2013) indicated that the chlorophyll of *A. pintoi* increased during the early stage of drought stress and then reduced later. In contrast, Sales *et al.* (2013) indicated that drought did not reduce total chlorophyll in the leaves of *A. pintoi*, which may be explained by the fact that there are fewer green leaves on plants





Note: Means accompanied by different letters are significantly different at the 5% level between treatments in each week after planting. The error bars represent the standard errors (SE) of the means.

Figure 4. Effects of water regimes (a) and fertilizer ratios (b) on SPAD readings of *A. pintoi*

Table 4. The interaction of water regimes and fertilization ratios on SPAD readings of *A. pintoi*

Water regimes	Fertilization ratios	SPAD		
		9 TST	12 TST	15 TST
W1	F1	38.1[ab]	35.7[c]	33.1
	F2	37.7[ab]	37.6[ab]	34.6
	F3	35.9[bcd]	33.3[de]	32.7
	F4	39.1[a]	38.2[a]	36.7
	F5	37.8[ab]	38.3[a]	36.3
	F6	39.0[a]	38.3[a]	36.3
W2	F1	36.9[abcd]	36.1[bc]	34.2
	F2	35.1[cde]	35.1[cd]	33.4
	F3	33.4[e]	33.6[de]	32.5
	F4	38.8[a]	38.5[a]	36.7
	F5	34.8[de]	36.1[bc]	35.6
	F6	35.0[cde]	34.9[cd]	35.9
W3	F1	35.6[bcd]	32.3[e]	32.7
	F2	35.6[bcd]	34.9[cd]	32.5
	F3	34.3[de]	32.6[e]	32.4
	F4	37.3[abcd]	36.7[abc]	35.5
	F5	36.9[abcd]	36.6[abc]	35.1
	F6	36.0[bcd]	36.1[bc]	35.5
ANOVA $_{(W\&F)}$		*	*	ns

Note: (ns): not significant, (*): significant at the 5% level. Values followed by different letters within a column indicate significant differences at the 5% level.

under drought stress. In our experiment, plants under water stress had higher SPAD readings. In addition, there was an increase in the SPAD readings for treatments with a higher nitrogen ratio at 12 and 15 WAP, which may have resulted from more available nitrogen.

The effects of the fertilization ratios and water regimes on dry matter of *A. pintoi*

The results in Table 5 show the significant effects of the water regimes and fertilization ratios on total dry matter (DM) and the root/shoot (R/S) ratio of *A. pintoi*. At 9 WAP, both water stress conditions (W1 and W2) significantly reduced total DM, but increased the R/S ratio in comparison to the well-watered treatment (W3). At 12 and 15 WAP, a lower DM measurement was observed in the higher water deficiency treatment, while the R/S ratio was not significantly different. Plants in the higher NP treatments (F5) induced lower R/S ratios at 9 and 12 WAP, and greater DM measurements at 15 WAP compared with those in the F1 treatments.

Under the severe drought treatments (W1) at 9 WAP, the higher P (F2) and higher NP (F5) treatments significantly increased total DM, whereas the R/S ratios were lower in comparison to F1. At 12 WAP and 15 WAP, higher NP significantly increased total DM while treatments with higher nitrogen and phosphate ratios reduced the R/S ratios compared with F1, except for the higher K treatments.

Under the mild drought treatments (W2), the effect of the fertilizer application ratios on total DM and the R/S ratio were not consistent. Increases in the N, K, NP, and NPK ratios at 9 WAP increased total DM compared with F1, whereas at 12WAP, a higher DM was found in the higher NP and higher NPK treatments.

Under well-watered conditions (W3), treatments with higher nitrogen ratios (F4, F5, and F6) significantly increased total DM at 9 WAP in comparison to the F1 and higher K (F3) treatments. At 12 WAP, high fertilization ratios significantly increased total DM as compared with F1, except with higher K. However, at 15 WAP, higher DM measurements were only found in the higher NP and higher NPK treatments.

Sales *et al.* (2012) observed an increase in the shoot/root ratio under high nitrogen fertilization, which means nitrogen fertilization reduced the R/S ratio. In our experiment, plants in the higher NP and higher NPK treatments induced a lower root/shoot ratio under drought, which may be due to the greater available nutrients in the study soil.

Table 5. The effects of the water regimes and fertilization ratios on total dry matter and root/shoot ratios of *A. pintoi*

Water regimes	Fertilizer ratios	9 WAP		12 WAP		15 WAP	
		Total DM (g/plant)	R/S ratio	Total DM (g/plant)	R/S ratio	Total DM (g/plant)	R/S ratio
W1	F1	0.30[g]	0.16[a]	0.94[l]	0.14[a]	4.33[hi]	0.08
	F2	0.46[ef]	0.14[ab]	0.97[kl]	0.11[bc]	4.48[ghi]	0.09
	F3	0.34[g]	0.14[ab]	0.88[l]	0.13[a]	4.55[fghi]	0.09
	F4	0.33[g]	0.14[ab]	0.89[l]	0.11[bc]	4.16[i]	0.08
	F5	0.41[f]	0.11[cd]	1.17[hik]	0.09[cde]	5.20[de]	0.09
	F6	0.40[f]	0.13[bc]	1.05[ikl]	0.09[cde]	4.32[hi]	0.09
W2	F1	0.34[g]	0.15[ab]	1.23[ghi]	0.11[bc]	4.94[defg]	0.09
	F2	0.32[g]	0.14[ab]	1.40[efg]	0.09[cde]	5.05[def]	0.09
	F3	0.4[f]	0.14[ab]	1.21[ghi]	0.12[ab]	4.73[efgh]	0.10
	F4	0.48[e]	0.13[bc]	1.33[fgh]	0.11[bc]	4.57[fghi]	0.10
	F5	0.55[d]	0.11[cd]	1.57[e]	0.08[de]	5.47[d]	0.09
	F6	0.51[de]	0.11[cd]	1.42[ef]	0.10[cd]	5.29[d]	0.09
W3	F1	0.66[c]	0.09[de]	2.05[d]	0.10[cd]	6.18[c]	0.09
	F2	0.70[bc]	0.09[de]	2.30[c]	0.11[bc]	6.30[bc]	0.09
	F3	0.65[c]	0.11[cd]	1.94[d]	0.12[ab]	6.41[bc]	0.10
	F4	0.73[b]	0.10[de]	2.29[c]	0.10[cd]	6.59[abc]	0.09
	F5	0.91[a]	0.08[e]	3.62[a]	0.07[e]	7.12[a]	0.10
	F6	0.89[a]	0.10[de]	2.98[b]	0.09[cde]	6.78[ab]	0.10
ANOVA $_{(W\&F)}$		*	*	*	*	*	ns
Water regimes							
W1		0.37[b]	0.14[a]	0.98[c]	0.11	4.51[c]	0.09
W2		0.44[b]	0.13[a]	1.36[b]	0.10	5.01[b]	0.09
W3		0.76[a]	0.09[b]	2.53[a]	0.10	6.56[a]	0.10
ANOVA $_{(W)}$		*	*	*	ns	*	ns
Fertilizer ratios							
F1		0.43	0.13[a]	1.41[b]	0.11[ab]	5.15	0.09
F2		0.49	0.12[ab]	1.56[ab]	0.10[bc]	5.28	0.09
F3		0.47	0.13[a]	1.34[b]	0.12[a]	5.23	0.10
F4		0.52	0.12[ab]	1.51[b]	0.11[ab]	5.11	0.09
F5		0.62	0.10[b]	2.12[a]	0.08[d]	5.93	0.09
F6		0.60	0.11[ab]	1.81[ab]	0.09[cd]	5.46	0.09
ANOVA $_{(F)}$		ns	*	*	*	ns	ns

Note: (ns): not significant, (*): significant at the 5% level. Values followed by different letters within a column indicate significant differences at the 5% level. DM: dry matter, R/S: root/shoot.

Sales *et al.* (2012) also indicated that nitrogen fertilization promoted dry matter accumulation of plants. The dry mass of green leaves was the highest at a dose of 80 kg N ha^{-1}, while the dry mass of stolons was the greatest at a dose of 120 kg N ha^{-1}. Also, there was a significant increase in the DM between 70 and 85 days after planting. In our experiment, a sharp increase in DM was observed after 12 WAP. This could be attributed to an increase in the number of leaves and leaf size, which are essential for the photosynthetic activity of the plant.

The positive effects of N and P on plant growth under water stress conditions have been reported in previous studies because they are attributed to an increase in water use efficiency. In maize, Studer *et al.* (2017) found a tendency for a reduction the R/S ratio when plants were supplemented with a nutrient supply compared to plants without fertilization. Drought conditions increased the R/S ratio in comparison to well-watered conditions, with the exception being in the NK treatment. Studer *et al.* (2017) also suggested that nutrient supplementation could improve drought tolerance under water deficient conditions by increasing plant biomass. In our experiment on *A. pintoi*, the positive impact of a higher NP ratio on growth of the plants under both water stress and well-water conditions was observed.

Conclusions

Our results confirmed a low growth rate of *A. pintoi* at the establishment stage. The availability of water showed a significant effect on the growth of primary stolons, number of leaves, secondary stolons, SPAD readings, and dry matter accumulation of *A. pintoi.* However, our experiment did not show a consistent impact of higher K, higher P, and higher N ratios on the growth of *A. pintoi* under drought conditions. Generally, under water stress conditions, higher NP and higher NPK ratios stimulated elongation of stolons, leaf appearance, and dry matter accumulation of plants, which suggest that the effects of fertilizer application under drought stress could be the result of the synergic effects of the combined fertilizer treatments. This was observed by the positive impact of higher NP on plant growth under both drought and well-irrigated conditions.

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