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Research Article

EVALUATION OF THE YIELD AND YIELD COMPONENTS OF GRAIN SORGHUM AND COWPEA INTERCROPPING UNDER DROUGHT STRESS AND DIFFERENT LEVELS OF PHOSPHORUS

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ABSTRACT
In order to investigate the effect of different levels of phosphorus chemical fertilizer on the yield and yield components of grain sorghum and cowpea intercropping (50% Sorghum + 50% Cowpea) under deficit irrigation conditions in Ahvaz, an experiment was carried out as split plots in the form of randomized complete block design with three replications in the summer of 2013. The main factors or the experiment included three humidity levels: 1. Optimal irrigation (irrigation after 6 days) 2. Mild stress (irrigation after 11 days) 3. Severe stress (irrigation after 16 days). The sub factor contained 4 levels of pure phosphorus including: lack of phosphorus assumption, 50, 90, 13 kg/ha pure phosphorus. The results showed that as the irrigation interval and phosphorus application increased number of grains per spike, number of spikelet per spike and grain yield of grain sorghum, 100-grain weight, number of grains per pod, and grain yield of cowpea respectively decreased and increased significantly. The maximum yields of cowpea (423.32 g/m^2) and grain sorghum (335.98 g/m^2) were achieved without irrigation stress (6-day irrigation interval) and as the irrigation interval increased from 6 days to 16 days the grain yield in cowpea and grain sorghum decreased by 56.13% and 58.22%, respectively. In summary, the results of this experiment showed that application of phosphorus fertilizer reduced the negative effects of water stress on the studied traits. Application of phosphorus fertilizer and optimal irrigation during the crop growth period led to the increase of grain yield of grain sorghum and cowpea.

Keywords: *Intercropping, Deficit Irrigation, Phosphorus Fertilizer, Yield and Yield Components*

INTRODUCTION
Due to more efficient use of resources and more complete coverage that it creates, intercropping is more advantageous than monoculture system. One of the advantages of intercropping over monoculture is the increase of yield which could be due to greater use of nutrients, light, decrease of weeds growth, or increase of consumption efficiency per each unit of resources (Bolson, 1997). Another advantage of intercropping over monoculture system is the decrease of pests and diseases, soil protection, improved efficiency of resources consumption, decrease of risk and weeds growth reduction (Hems, 1999). One of the major factors of the decrease of crops yield around the world is water restriction and lack of proper distribution of it during the growth season. Deficit irrigation is one of the solutions to optimize water consumption during which the crops are allowed to tolerate some water stress during the growth season (Wang *et al*., 2001). Deficit irrigation might cause the decrease of yield per area unit, but it finally leads to the increase of cultivation area and maximum capacity of crops production in an area. Phosphorus is an essential element for all living organs such as plant organs and after nitrogen it is the second major element restricting plants growth (Kanbolat *et al*., 2006).
Planting resistant plants, recognizing the relationship between shortage of water, soil, and growth of crops at every growth stage, using new irrigation methods and increasing irrigation efficiency in this respect will be useful and desirable. One of the agricultural solutions to the increase of water productivity is intercropping for the optimal use of soil moisture (Sanjani, 2007). Grain sorghum and cowpea intercropping has been chosen due to certain characteristics which will be referred to in the following for effective use of available water to produce maximum crops. Both crops are resistant to drought stress and can be used in arid and semiarid areas as reliable sources for production of grains and forage.

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MATERIALS AND METHODS

In order to examine the effect of irrigation regimes and different levels of phosphorus fertilizer this research was carried out in the summer of 2013 in Albaji Field located in Ahvaz (at latitude 43˚10' N and longitude 32˚11' E and 120 m above the sea level.

Absorbable Phosphorus P (mg/kg)		**Soil reaction (pH)**	**Electric conductivity EC (dS/m)**	**Sampling depth (cm)**	**Lab No.**
5		7/7	3/9	0-30	1
1/2		7/8	4/5	30-60	2
Clay (%)	Silt (%)	Sand (%)	Sodium (meq/Lit)	Absorbable potassium K (mg/kg)	Lab No.
15	16	69	17	187	1
15	26	59	20	212	2

The research was carried out as a split plot experiment in the form of randomized complete block design with three replications. The experimental factors included three irrigation levels as the main plot (I_1= 6days, I_2 = 11 days, I_3 = 16 days) and the sub plot contained 4 levels of pure phosphorus including: lack of phosphorus assumption, 50, 90, 13 kg/ha pure phosphorus, 8 planting rows as long as 8 m and with equal proportions (4 rows of grain sorghum and 4 rows of cowpea as alternate rows) and the distance between rows was 60 cm for two crops. The common cultivar of cowpea seeds in Ahvaz named Kamran cultivar with density of 75000 plants per area unit and 12 cm spaced from each other and the seeds of grain sorghum (Kimia cultivar) with density of 65000 plants per area unit and 15 cm spaced from each other were planted in early July, 2013. Planting was done manually and in piles, so that in each spot 2-3 seeds were planted for better emergence. The required phosphorus was supplied from triple superphosphate source and all of it was distributed as a strip before planting. Until the 4-leaf stage (plant establishment stage) irrigation was done in a 6-day interval and after the full plant establishment irrigation treatments were applied.

Yield components including the number of spikelet per spike, number of grains per spikelet, and 1000-grain weight (based on 10 plants in each plot in average after removing marginal effect) were separately measured after the final harvest in each plot. For the cowpea, grain yield and yield components including the number of pods per plant, pod length, number of grains per pod, 1000-grain weight, and plant height were determined by measuring the mean of 10 plants in each plot randomly.

RESULTS AND DISCUSSION

Number of Grains per Spike in Grain Sorghum and Number of Grains per Pod in Cowpea in Intercropping

The results showed that irrigation interval and phosphate fertilizer had a significant effect on the number of grains per spike in sorghum and also on number of grains per pod in cowpea at1% level. The results were consistent with the findings of Alipoor (2011). However, their interactive effect on the trait was not significant. The increase of the number of grains per spike in grain sorghum in the treatment with application of 50 kg/ha phosphate fertilizer was about 15% more than the control treatment which could play a significant role in increasing the yield. It seems like that as the irrigation interval increases and drought stress condition is provided the absorption of phosphorus in soil by plant is done slowly and its increase does not have a significant effect on the improvement of the traits associated with yield components of grain sorghum. Santos *et al.*, (2006) stated that failure to provide necessary assimilates for the growth of embryo and development of seed is one of the major causes of the reduction of number of grains per pod under drought stress conditions. Cowpea is a crop which grows rapidly, therefore it should access sufficient water in soil to grow optimally and to have optimal yield. Mean comparison results of the effect of phosphate fertilizer on the number of grains per pod indicated that there was a significant difference between the treatments with 90 and 130 kg/ha phosphate and the control treatment (without fertilizer consumption), but there was not a significant difference between the control treatment and the treatment with application of 50 kg/ha phosphate fertilizer.

Grain Yield of Grain Sorghum and Cowpea in Intercropping

The grain yield was affected by the treatments of irrigation intervals, phosphate fertilizer, and their interactive effect. As the irrigation interval increase, the grain yield of grain sorghum intercropped with cowpea decreased significantly. Even though there was no significant difference between the treatments with application of 90 and 130 kg/ha phosphorus fertilizer, in comparison with the control treatment (without consumption of phosphorus fertilizer) there was a significant difference between all consumption levels of phosphorus fertilizer. It seems like that in intercropping conditions in order to achieve optimal grain yield in grain sorghum, application of at least 90 kg/ha phosphate fertilizer is necessary.

Phosphorus increases the plant ability to absorb water by stimulating the root growth, and the increase of phospohrus uptake by plant decreases and adjusts the effects of drought stress and meanwhile leads to the increase of root growth and phosphorus absorption which in turn leads to the increase of root hydraulic conductivity and resistance to drought stress. The results showed that under the increase of irrigation interval to 16 days, application of different levels of phosphate fertilizer did not increase the grain yield of sorghum significantly and it was not significantly different from the control treatment. This indicates that under drought stress conditions, phosphorus uptake in soil is impaired and the rate of its absorption reduces dramatically.

The ANOVA results indicated that there was a significant difference between different irrigation intervals and their effects on the grain yield of cowpea at 1% level. The results of the research were consistent with the reports of Al-Seraj (2013).

In this experiment the high rate of grain yield under optimal irrihation cinsitions (6-day irrigation interval) is associated with superiority in terms of green cover percentage, effective period and rate of grain filling and the yield components, i.e. the number of pods per plant and the weight of grain in comparison with limited irrigations. Longer continuity of green cover in full irrigation and superiority of vegetation can lead to the increase of grain yield throgh increasing the length of photosynthesis process. It seems like that tge effect of drought stress on grain yield results from the fact that at the end of growth period due to lack of accessible water the strength of assimilates mobilization into grains declines and leads to the decrease of grain yield under the increase of irrigation interval. The reduction of grainyield in this research under the increase of irrigation interval can be attributed to the decrease of number of pods per plant and the decrease of 100-grain weight. Since the grain yield is a part of total dry matter produced by plant, the decrease of plant dry matter under stress conditions can justify some part of grain yield reduction.mean comparison results showed that different levels of phosphate fertilizer had a significant effect on grain yield of cowpea. This seems to be due the positive effect of phosphate fertilizer on the weight of 1000-grain and number of pods per plant which ultimately leads to the increase of grain yield.

Plant resistance enhancement might be related to the increase of phosphorus uptake by plant in soils where the amount of accessible phosphorus is low.

1000-Grain Weight in Grain Sorghum and Cowpea Intercropping

High weight of 1000-grain increases the yield. 1000-grain weight depends on four factors of grain fiiling filling stage duration, number of active leaves in reproductive stage, leaf area, and stem dry weight.

As the irrigation interval increased, 1000-grain weight decreased significantly. Farasat *et al.,* (2012) believe that under drought stress conditions as the plant faces water deficit stress since the beginning of growth and the self-reglatory mechanism of plant is consequently based on a limited number of grains, the plant will be able to fill that number of grains during the growth stage. On the other hand, they state that 1000-grain weight is less affected by inappropriate environmental conditions while other yield components are more affected by environmental factors. The decrease of sorghum 1000-grain weight with

the increase of irrigation interval has often resulted from the intensification of interspecies and intraspecies competition with cowpea on the use of available sources.
The results showed that the effect of phosphate fertilizer and the interactive effect of irrigation interval and phosphate fertilizer on 1000-grain weight of cowpea intercropped with grain sorghum was significant at 5% level.

Table 1: The ANOVA results of the effect of irrigation interval and different levels of phosphate fertilizer on yield and yield components of grain sorghum and cowpea intercropping

Mean of Squares (MS)				
Grain Yield	**1000-grain weight ٥**	**Number of grains per spike**	**df**	**Sources of Variations**
839/82$^{n.s}$	7/18$^{n.s}$	8/12$^{n.s}$	2	Replication (block)
173028/65**	183/1**	414/63**	2	Irrigation interval (I)
1721/25	3/95	12/35	4	Major error
14658/8**	5/76*	23/53**	3	Phosphate fertilizer (P)
4942/19**	0/63$^{n.s}$	1/47$^{n.s}$	6	I×P
466/18	1/51	1/93	18	Minor error
7/33	5/01	6/26	Coefficient of variations (CV%)	

**, **, n.s respectively indicate significant at 5%, 1% levels and non-significant difference*

Table 2: The ANOVA results of the effect of irrigation interval and different levels of phosphate fertilizer on yield and yield components of cowpea intercropped with grain sorghum

Mean of Squares (MS)				
Grain yield	**100-grain weight**	**Number of grains per pod**	**df**	**Sources of variations**
666/96$^{n.s}$	2/28$^{n.s}$	0/03$^{n.s}$	2	Replication (block)
114879/96**	150/7**	51/13**	2	Irrigation interval (I)
254/83	7/94	0/29	4	Major error
5937/15**	1/12*	0/4*	3	Phosphate fertilizer (P)
105/61$^{n.s}$	1/33*	0/01$^{n.s}$	6	I×P
282/05	0/34	0/1	18	Minor error
7/09	2/66	3/13	Coefficient of variations (CV%)	

**, **, n.s respectively indicates significant at 5%, 1% levels and non-significant difference*

Table 3: Mean comparison of the simple effects of irrigation interval and different levels of phosphorus fertilizer on yield and yield components of grain sorghum intercropped with cowpea

Grain yield (g/m2)	1000-grain weight (g)	Number of grains per spike	Treatment
423/32^{a}	27/96^{a}	28/49^{a}	6 day
274/31^{b}	25/35^{b}	21/37^{b}	11 day
185/71^{c}	20/28^{c}	16/83^{c}	16 day
239/97^{c}	23/57^{b}	19/91^{b}	0 kg/ha^{-1}
288/38^{b}	24/16^{ab}	22/36^{a}	50 kg/ha^{-1}
319/73^{a}	25/16^{a}	23/23^{a}	90 kg/ha^{-1}
329/7^{a}	25/22^{a}	23/43^{a}	130 kg/ha^{-1}

According to Duncan's multi range test, the means with common letters in each column are not significantly different at 5% level.

It seems like that the decrease of 1000-grain weight with the increase of irrigation level was due to reduction of assimilates mobilization into grain because of the decrease of grain filling duration. County Chondory *et al.*, (2011) reported the decrease of 1000-grain weight under drought stress for various genotypes of bean and stated that the decrease of grain weight was due to the decrease of grain filling period which is consistent with the findings of this research.

Table 4: Mean comparison of the simple effects of irrigation interval and different levels of phosphorus fertilizer on yield and yield components of cowpea intercropped with grain sorghum

Grain yield (g/m2)	100-grain weight (g)	Number of grains per pod	Treatment
335/98[a]	25/07[a]	11/83[a]	6 day
234/23[b]	22/92[b]	10/67[b]	11 day
140/34[c]	18/15[c]	7/81[c]	16 day
208/39[c]	21/55[b]	9/82[b]	0 kg/ha^{-1}
226/6[bc]	22/03[ab]	10/08[ab]	50 kg/ha^{-1}
243/68[b]	22/3[a]	10/21[a]	90 kg/ha^{-1}
268/74[a]	22/29[a]	10/31[a]	130 kg/ha^{-1}

According to Duncan's multi range test, the means with common letters in each column are not significantly different at 5% level.

Table 5: Mean comparison of the interactive effects of irrigation interval and different levels of phosphorus fertilizer on yield and yield components of grain sorghum intercropped with cowpea

Grain yield (g/m2)	1000-grain weight (g)	Number of grains per spike	Treatment
307/37[c]	26/6[a]	1095[c]	I_1P_0
411/56[b]	27/66[a]	1386/66[b]	I_1P_1
474/49[a]	28/33[a]	1569/66[a]	I_1P_2
499/85[a]	29/26[a]	1606/66[a]	I_1P_3
238/01[e]	24/6[a]	1079/33[cd]	I_2P_0
268/52[de]	25/13[a]	1032[cd]	I_2P_1
297/7[cd]	26/26[a]	985/33[de]	I_2P_2
293/02[cd]	25/4[a]	975[de]	I_2P_3
174/53[f]	19/53[a]	631/66[g]	I_3P_0
185/07[f]	19/7[a]	880[ef]	I_3P_1
186/99[f]	20/9[a]	829/33[f]	I_3P_2
196/24[f]	21[a]	795/66[f]	I_3P_3

According to Duncan's multi range test, the means with common letters in each column are not significantly different at 5% level.

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Table 6: Mean comparison of the interactive effects of irrigation interval and different levels of phosphorus fertilizer on yield and yield components of cowpea intercropped with grain sorghum

Grain yield (g/m2)	100-grain weight (g)	Number of grains per pod	Treatment
299/65[a]	23/96[b]	11/56[a]	I_1P_0
329/18[a]	25/05[a]	11/83[a]	I_1P_1
341/55[a]	25/35[a]	11/91[a]	I_1P_2
373/53[a]	25/93[a]	12/01[a]	I_1P_3
207/4[a]	22/1[d]	10/33[a]	I_2P_0
220/69[a]	22/76[cd]	10/57[a]	I_2P_1
241/39[a]	23/43[bc]	10/8[a]	I_2P_2
267/45[a]	23/39[bc]	10/97[a]	I_2P_3
118/1[a]	18/6[e]	7/56[a]	I_3P_0
129/93[a]	18/3[ef]	7/83[a]	I_3P_1
148/09[a]	18/13[ef]	7/91[a]	I_3P_2
165/25[a]	17/56[f]	7/96[a]	I_3P_3

According to Duncan's multi range test, the means with common letters in each column are not significantly different at 5% level.

Conclusion

Considering the mentioned points, application of deficit irrigation systems and consumption of phosphate ferilizers form an appropriate combination of sustainable management for crop production under limited water condition and make the soil frtile. In present study, grain sorghum and cowpea intercropping has been selected for effective utilization of available water to produce maximum yield since both crops have certain properties such as tolerance of drought stress, ability to compete effectively with grass weeds, and short growth period.

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