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Provenance Variation in seed germination, early seedling growth and water consumption of Hashab *(Acacia senegal)* on Clay Soils of Sudan

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Abstract: The aim of this study is to assess the variability and differences in seed germination, early seedling growth and water efficiency among *Acacia senegal* provenances from the central clay plains of Sudan. Twelve locations throughout the clay part of the gum belt were identified as seed sources according to geographical discontinuity and differences in annual rainfall. Three irrigation intervals (every three, six and twelve days) were applied. To estimate the transpiration rate three bags in each cemented bed were kept without seedling and treated like the other bags in the same bed containing seedlings. All bags were weighed before and after irrigation allowing 5 minutes for drainage of excess irrigation water. Transpiration was calculated according to the irrigation treatments schedules from the differences in water loss between the bags with plants and those without plants. The irrigation interval had significant effect on germination percentage and seedling growth. The root/shoot ratio increased with the prolonged irrigation schedule. This indicated that the seedlings have tendency to allocate more dry matter to the root system and increase its growth and biomass as an adaptation against the dry soil conditions. However, there were some significant differences on the growth parameters in the interactions between the irrigation treatments and the hashab provenances. Most of the provenances showed close transpiration rate with some exceptions. The water use efficiency of the seedlings from the different provenances also varied and showed significant differences. This study concludes that seedlings of *Acacia senegal* have variability in growth performance. Also the seedlings growth is checked by the moisture availability in the soil and seedlings with high drought tolerance maximize the use of the moisture to build their biomass.

Keywords: Seed germination, early seedling growth, water use efficiency, provenance variation, *Acacia senegal*

Introduction

*Acacia senegal (*Hashab) is an important forest tree species in Sudan due to its economical and ecological benefits. It produces gum arabic and contributes to combating desertification (Warrag *et al.*, 2002) and provides a wide range of products including fuel wood and fodder (Ahmed, 2005). It is found on sandy and clay plains in short grass on dark cracking clay of the Central and Eastern Sudan, it is not usually found as pure stands as on the sands. It water requirement appears to be intermediate between *Acacia mellifera* and *Acacia seyal*, and it is usually found mixed with one of these species (Badi *et al.*, 1989).

The central clay plains of the Sudan exhibit considerable variation in rainfall throughout its geographic locations. Accordingly, *Acacia senegal* geographical sources may have interacted and adapted to the environmental and soil conditions of each of geographical locations (Ahmed, 2005). These environmental interactions and adaptations might have been phenotypic variations among the populations grown in the different geographical locations of the central clay plain.

Water-use efficiency describes a plant's photosynthetic production rate relative to the rate at which it transpires water to the atmosphere. It is a measure of plant performance that has long been of interest to agronomists, foresters and ecologists (Bacon, 2004). In cropping systems, improving water-use efficiency presents a means of increasing crop production in the face of finite water supplies (Richards *et al*., 2002). In forestry systems, water-use efficiency is a critical link between wood production and water management. In global-change research, water-use efficiency links the carbon and water cycles of terrestrial vegetation, and is expected to increase in a future high carbon dioxide world (Guehl *et al*., 1994; Farquhar, 1997; Winter *et al*., 2001).

The aim of this study was to assess the magnitude of variability and differences in seed germination, early seedlings growth and water use efficiency among the provenances of *Acacia senegal* in the central clay plains of the Sudan. Specific objectives were to: assess and monitor the seed germination, early seedling growth, monitor the transpiration rate and compute the water use efficiency of hashab from different provenances subjected to different irrigation regimes.

Materials and Methods

Seed sources: Twelve provenances from the clay plain of the gum belt were identified as seed sources according to geographical discontinuity and differences in annual rainfall (Table 1). The provenances were chosen to represent the natural range of hashab in clay soils. The locations were: Abu Jebeha, Gulhak, Bout, Abu Gumai, Khor Dunia, Mazmoum, Abu Dolau, Karkoj, Hawata, Qala en ahal, Houri, and Rwashda .

Table 1. Location and rainfall (mm) within the geographical seed sources of *Acacia senegal* .

Provenances	Longitude[1]	Latitude[1]	Rainfall[2] (mm)
Abu Jebeha	31° 00″ E	11-° 00″ N	697.2
Gulhak	32° 40″ E	11° 00″ N	726.2
Bout	33° 33″ E	11° 48″ N	592.2
Abu Gumai	34° 25″ E	11° 35″ N	700
Khor Dunia	34° 05″ E	11°- N	678.7
Mazmoum	33° 35″ E	12° 10″ N	625
Abu Dolau	32° 45″ E	12° 25″ N	489.8
Karkoj	34° 00″ E	13° 00″ N	600
Hawata	34° 24″ E	13° 30″ N	589.7
Qala en ahal	35° 00″ E	14° 36″ N	672.7
Houri	35° 06″ E	14° 02″ N	544.8
Rwashda	35° 42″ E	14° 14″ N	597.4

*Source
1: Forest National Corporation
2: Mechanized farm administration for Elgadrif and El Damazin

The seed were collected from ten randomly selected trees in a forest in each location. The selected trees were at least 100 meters apart. Pods were collected from each tree separately and the seeds were extracted manually and cleaned from debris .The clean seed from the trees of each source were bulked together.

Layout and design of the experiment:
The experiment was conducted at the Forestry Research Center nursery at Soba. The treatments comprised the twelve provenances and irrigation levels viz every three, six and twelve days. Nine cemented seed beds were assigned for the study and divided into three replications and the three irrigation treatments were assigned randomly to beds in each replication. Polyethylene bags (20 cm×20 cm) were filled with clay soil and three seeds from each provenance were sawn in each bag. Different provenances were assigned randomly within each cemented seed bed. Each source was represented with 84 bags arranged in row plots in the seed bed. In addition, three bags without seeds were included in each cemented bed and treated similarly to other polythene bags with seeds and later on with seedlings. The beds were flood irrigated immediately after seed planting and thereafter according to the assigned irrigation treatment for each bed.

Germination count
Seed germination was counted every 6 days after sowing for 54 days. Thereafter, the seedlings were thinned to one per bag and the surface of the soil for each bag was covered with polyethylene sheet of the same material of the polythene bags.

Sampling and measurements
Seven seedlings per each provenance per replication per irrigation regeme were taken randomly at age 3 and 6 month from seed sowing and measured for shoot length using cm-graded ruler. Also, after six months from sowing seven seedlings per provenance per replication per irrigation regeme were randomly taken and harvested. The harvested seedlings were separated to shoot and root and weighed, then oven dried at 80˚C and weighed using sensitive balance.

Transpiration measurements
Three bags were weighed before and after irrigation allowing 5 minutes for drainage of excess irrigation water, including those with and without seedlings. Transpiration was calculated according to the irrigation treatments (every three, six and twelve days) from the differences in water loss between the bags with seedlings and those without seedlings.

Data analysis

Analysis of variance ANOVA was carried using JMP statistical package version (3.2.2). Comparisons among the means were made according to Tukey-Kramer HSD at 0.05 level of significance.

Results

Irrigation frequency had significant effect (p=0.0001) on the seed germination percentage of *Acacia senegal* after six days from seed sowing until 54 days (Table 2). The differences were more noticeable after 12 days. The germination percentage increased significantly from irrigation every 12 days to 6 days to 3 days. The effect of the irrigation interval on shoot height, shoot weight, root weight and root to shoot ratio was also significant (Table 3). The seedlings shoot height showed significant variation among the *Acacia senegal* provenances at the three months only (Table 4) while no significant differences were observed in the other growth parameters (Table 5). The interaction between the irrigation treatments and the provenances was significantly not differences for some growth parameters. The differences in root fresh weight (Table 5) are more noticeable on the seedlings subjected to 6 or 12 days irrigation schedules. The cumulative water transpiration (water use) of the seedlings for the twelve geographical sources during the experiment period is illustrated in Figure 1. Most of the seedlings showed close transpiration rate with some exceptions (Figure 2).

Table 2: Effect of irrigation interval on seed germination percentage of *Acacia senegal*.

Irrigation	Day 6	Day12	Day18	Day24	Day30	Day36	Day42	Day48	Day54
3 days	14.95a	43.78a	59.26a	60.60a	61.18a	61.74a	62.05a	62.25a	62.25a
6 days	8.50b	29.83b	42.51b	43.78b	44.44b	45.01b	45.82b	46.49b	46.37b
12 days	11.21c	17.21c	17.20c	28.69c	29.80c	30.37c	31.94c	36.09c	36.72c
P=	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**

Table 3: Effect of irrigation interval on shoot (cm) and root biomass (g) of *Acacia senegal*

Irrigation Schedule	Height (cm) 3 months	Height (cm) 6 months	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Root/Shoot ratio
3 days	40.81a	67.66a	66.80a	36.19a	36.94a	20.00a	0.69b
6 days	36.50b	64.16b	45.36b	25.86b	30.10b	16.62b	0.81a
12 days	31.01c	58.14c	41.15c	23.05c	25.90c	14.56c	0.82a
P=	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Means with the same letters in the same column are not significantly different at p= 0.05 Tukkey-Kramer HSD.

Table 4: Seedlings mean height (cm) of 3 and 6 month-old *Acacia senegal* of provenances

Provenances	Height after 3 months	Height after 6 months
1- Abu Jebeha	35.06 ab	62.00 ns*
2- Gulhak	33.21 b	58.64 ns
3- Bout	35.43 ab	63.63 ns
4- Abu Gumai	38.12 a	68.88 ns
5- Khor Dunia	36.77 ab	60.05 ns
6- Mazmoum	34.54 ab	60.77 ns
7- Abu Dolau	35.76 ab	63.19 ns
8- Karkoj	36.94 ab	64.78 ns
9- Hawata	36.29 ab	64.20 ns
10- Qala en Nahel	36.88 ab	62.64 ns
11- Houri	36.89 ab	65.44 ns
12- Rawashda	37.56 ab	65.75 ns
P-value	0.06	0.2

Means with the same letter in the same column are not significantly different at p= 0.05 Tukkey-Kramer HSD. *ns= not significant

Table 5: Mean weights of some growth parameters of *Acacia senegal* seedlings from different provenances subjected to different irrigation schedules.

Provenances	Shoot fresh weight (g)			Shoot dry weight (g)			Root fresh weight (g)			Root dry weight (g)		
	3d IR	6d IR	12d IR	3d IR	6d IR	12d IR	3d IR	6d IR	12d IR	3d IR	6d IR	12d IR
Abu Jebeha	64.30	40.4	39.23	34.1	24.84	21.04	32.26	30.82	20.78	17.6	17.64	11.88
Gulhak	47.71	38.95	33.53	25.63	23.44	17.44	32.15	28.05	22.21	17.58	15.94	12.23
Bout	81.76	31.09	41.99	43.94	19.64	23.66	40.90	23.23	25.29	21.36	13.79	14.24
Abu Gumai	73.80	36.53	50.09	42.61	22.46	27.7	41.04	28	29.17	21.52	16.01	16.9
Khor Dunia	79.00	53.74	44.72	43.61	32.57	24.45	36.50	31.91	24.61	19.34	18.46	13.71
Mazmoum	62.28	57.51	37.52	32.79	34.64	20.59	34.65	34.23	25.24	18.54	19.86	13.66
Abu Dolau	66.98	44.06	30.24	37.51	27.08	18.35	38.59	22.61	21.63	21.74	13.31	12.17
Karkoj	73.76	43.04	45.56	38.18	25.16	24.09	43.40	26.24	32.51	22.71	14.68	12.69
Hawata	65.31	45.5	39.13	33.98	25.76	12.8	38.00	26.84	24.96	21.19	15.63	13.83
QalaElNahel	61.00	33.08	38.11	33.68	20.26	22.79	36.44	23.34	25.68	20.17	13.98	14.83
Houri	65.63	41.44	49.27	35.4	25.69	28.46	32.31	35.46	28.16	17.84	20.56	15.65
Rawashda	60.08	46.21	44.43	33.42	30.02	26.25	37.11	32	30.54	20.44	18.34	17.94
P =	0.5	0.7	0.8	0.4	0.1	0.7	0.08	0.1	0.2	0.2	0.2	0.2

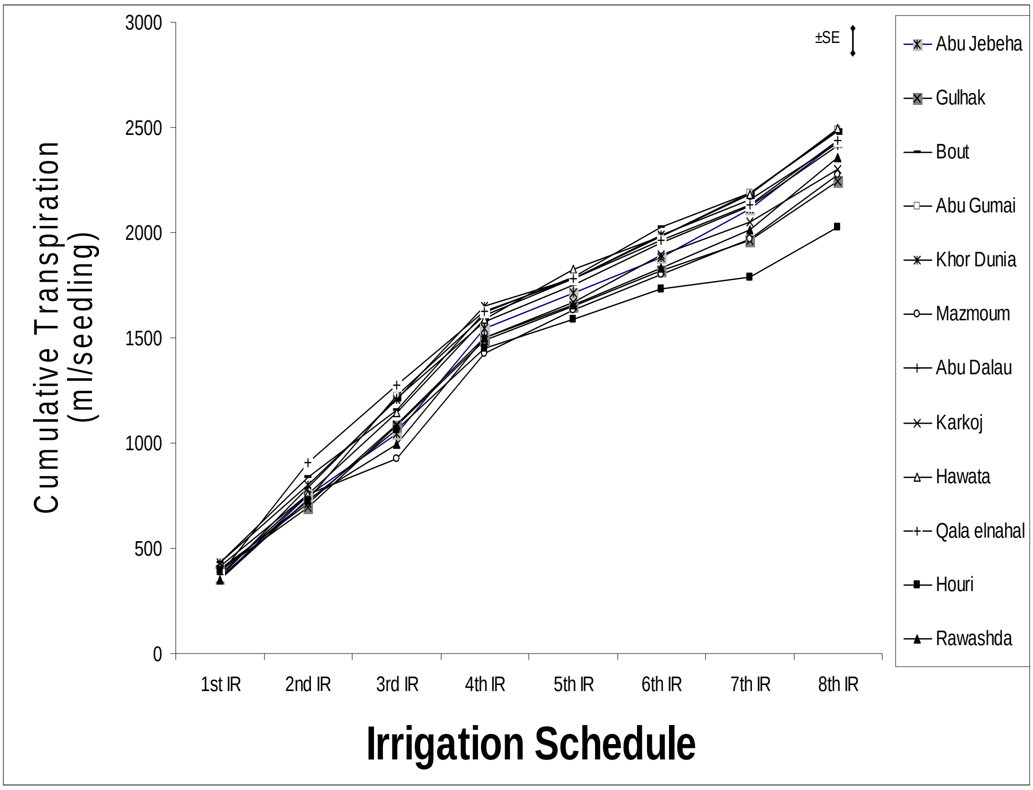

Figure 1: Cumulative transpiration of *Acacia senegal* seedlings of twelve different provenances. Thevertical bar-line indicates ± the experimental standard error

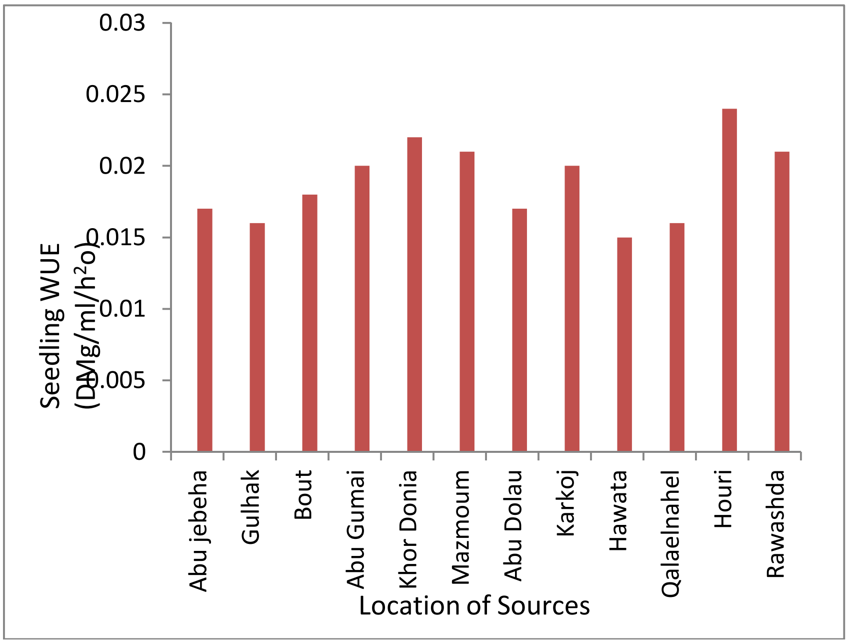

Figure 2: Water use efficiency (WUE) of *Acacia senegal* from twelve provenances. The vertical bar-line indicates ± the standard error of the mea

Discussion

McLaren1 and McDonald (2003) had similar findings for the effects of watering intervals on germination of tree species. Also, the present results are in agreement with the findings of Bebawi and Mohamed (1982) on some *Acacia* species, where they concluded that maximum germination can be obtained using daily irrigation. Although, the germination percentage for the irrigation treatment of every 12 days is lower than the other two treatments, but still considerable (ranging from 11.2% to 36.7 after 6 and 54 days from sowing, respectively. This may reflect the adaptability of the species to dry conditions.

The present study showed that the growth of the *Acacia senegal* seedlings was checked by the shortages of soil moisture availability and the root/shoot ratio was significantly higher for the treatments of 6 days and 12 days irrigation intervals as compared to 3 days interval. This indicates that the seedling have a tendency to allocate more dry matter to the root system and increase the growth and biomass as a strategy to adapt to the dry soil conditions. Liu *et al*., (2004) showed that drought increases the shoot-root ratio and that was associated with increases in root respiration rate. Also, Barton and Montagu (2006) showed similar results in *Eucalyptus* and attributed the increase in the shoot root ratio to the increase in the adventitious roots. Also, significant differences were found on the interactions between the irrigation treatments and the geographical locations for some growth parameters. This finding might be attributed to some environmental and genetic differences inherited in the seeds from different locations (Warrag *et al*., 2002).

Houri provenance exhibited the lowest transpiration rate, highest water use efficiency among all the sources. There were evidences of strong association between the efficient use of water and the drought tolerant species (Craven *et al.* 2010). These results support the findings of Raddad and Luukkanen (2006) on the adaptive genetic variation in water-use-efficiency of Acacia *senegal* provenances.

Conclusions and Recommendations

This study concludes that the seedlings of Hashab (*Acacia senegal*) from twelve geographical sources, representing the clay part of the gum belt, are variability in some growth parameters like shoot height. This can be attributed to the environmental-genetic interaction that is intrinsic in the seeds to perform in the future. Also the seedlings growth is checked by the moisture availability in the soil and seedlings with high drought tolerance maximize the use of the moisture to build their biomass. It is recommended that the study need to be verified further by physiological data coupled with some cytogenetic and biotechnology techniques to distinguish the genetic variation between the sources of the Hashab seeds.

References

Ahmed, A.S., (2005). Individual and geographical location variations in seed characteristics, germination and seedlings growth of *Acacia senegal var.senegal from clay soils of Sudan*. M.Sc thesis. University of Khartoum.

Bacon, MA, ed. (2004). *Water use efficiency in plant biology*. Blackwell Publishing, Oxford, UK

Badi, K.H., Ahmed, E.A. and Bayoumi, A.A., (1989). The forest of the Sudan. *Agricultural Research Council (NCR)* Khartoum, Sudan.

Barton, CVM & Montagu, KD (2006). Effect of spacing and water availability on root: shoot ratio in *Eucalyptus camaldulensis Forest Ecology and Management*, vol, **221**, no. 1-3, pp. 52-62.

Bebawi, FF. and Mohamed SM. (1982). Effects of irrigation frequency on germination and on root and shoot yields of Acacia species. *Plant and Soil* **65** (2) 275-279.

Cravena, D., Gulamhusseina S., and Berlyna G.P. (2010). Physiological and anatomical responses of *Acacia koa* (Gray) seedlings to varying light and drought conditions. *Environmental and Experimental Botany* **69** (2) 205-213.

Farquhar GD., (1997). Carbon dioxide and vegetation. *Science* **278**: 1411

Guehl JM, Picon C, Aussenac G, Gross P. (1994). Interactive effects of elevated CO2 and soil drought on growth and transpiration efficiency and its determinants in *two European forest tree species*. *Tree Physiology* **14**:707–724.

Liu HS, Li FM, and Xu H. (2004). Deficiency of water can enhance root respiration rate of drought-sensitive but not drought-tolerant *spring wheat*. *Agricultural Water Management* **64** (1) 41-48.

McLaren1 K. P and McDonald M.A. (2003). The effects of moisture and shade on seed germination and seedling survival in tropical dry forest in Jamaica. *For. Ecol. Manage*. **183** (1): 61-75.

Raddad E. Y. and Luukkanen O. (2006). Adaptive genetic variation in water-use efficiency and gum yield in *Acacia senegal* provenances grown on clay soil in the Blue Nile region, Sudan. *Forest Ecology and Management*. **226** (1-3) 219-229

Richards RA, Rebetzke GJ, Condon AG, van Herwaarden AF. (2002). Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. *Crop Science* **42**:111–121.

Warrag, E.I, Elsheiksh, E.A., and Efeel, A.A., (2002). Forest genetic conservation resources 30, pg.70.

Winter K, Aranda J, Garcia M, Virgo A, Paton SR. (2001). Effect of elevated CO2 and soil fertilization on whole-plant growth and water use in seedlings of a tropical pioneer tree, *Ficus insipida Willd*. *Flora* **196**: 458 – 464.

التباين فى إنبات البذور ونمو الشتول و كفاءة إستخدام الماء لشجرة الهشاب من مصادر جغرافية مختلفة على الترب الطينية فى السودان

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المستخلص

الهدف من هذه الدراسة هو تقييم مستويات التباين والاختلاف في إنبات البذور ونمو الشتول وكفاءة استخدام المياه بين الهشاب من مصادر جغرافية مختلفة في السهول الطينية الوسطى من السودان. وقد تم تحديد إثني عشر مواقعاً جغرافياً وفقا للتباعد الجغرافي والاختلاف في معدل هطول الأمطار السنوي على مدى حزام الصمغ العربى وكانت العوامل المدروسة هى المصادر الجغرافية ونظام الري مع ثلاثة مستويات (كل ثلاثة أيام ، ستة واثني عشر يوماً). من أجل تقديرمعدل النتح تم أخذ ثلاثة أكياس خالية من الشتلات في كل تكرار وتعامل مثل باقى الاكياس التي تحتوي على الشتول كشاهد للتجربة. وتم وزن جميع الأكياس قبل وبعد الري. تم حساب معدل النتح وفقا لعامل الري وهو عباره عن الاختلافات في فقدان المياه بين أكياس ذات النباتات و أكياس الشاهد. أظهرت هذه الدراسة أن نسبة الإنبات تختلف إختلافا كبيرًا بين مستويات الري.و كما تظهر الدراسة وجود تأثير معنوى من مستويات الرى على خصائص النمو. معدل نسبة الجذر / للساق تزيد بزيادة عدد مرات الر وهذا يدل على أن نمو شتول الهشاب يتحدد عن طريق نقص رطوبة التربة. هذا يدل على تخصيص المزيد من المادة الجافة إلى نظام الجذور مما يؤدى لزيادة نموها والكتلة الحية كإستراتيجية لمواجهة ظروف التربة الجافة. توجد بعض الاختلافات المعنوية لخصائص النمو في فى حالة تداخل عامل الرى مع عامل المصادر الجغرافية. أظهرت الدراسة تشابه معدل النتح لشتول الهشاب مع وجود بعض الاستثناءات. و أيضًا أظهرت إختلافات بين المواقع الجغرافية فى كفاءة استخدام المياه. خلصت هذه الدراسة إلى أن شتول الهشاب أظهرت تبايناُ فى خصائص النمو. كما أن نمو الشتول يعتمد على وفرة رطوبة التربة حتى تتمكن من تحمل الجفاف و الإستفادة القصوى من الرطوبة لبناء كتلتها.