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Germination performance of some legume crops under varying soil water available capacities

Iqbal Murad Thahir[1], Al-Rawi Caser G Abdel[2*]

[1]*Field Crops, Salahalddin University, Iraq*

[2]*Horticulture, Dohuk University, Iraq*

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Abstract

A laboratory attempt was made to evaluate germination performances of three lentil cultivars namely Nineveh, Adlib and Baraka, besides Common Vetch and Mungbeans under varying soil water availabilities. Soils were moistened to 100, 75, 50 and 25% of its water available capacity and were used as germinating media. Germinating seeds in 0% soil AWC depletion was surpassed over that of 25, 50 and 75% depletion of AWC in terms of final germination percentage (2.8, 13.3, 53.2%, respectively), radical length (16.6, 48 and 129.1 %, respectively), plumule length (27.5, 34.8 and 128 %, respectively). This treatment also revealed substantial reductions in days required for peak germination (36, 50.8 and 63.9, respectively) and days required for first emergence (5.6, 50 and 75%, respectively). Thus, treatments can be arranged according to their adversities as below: 75%>50%>25%>0% depletion out of soil AWC. Mungbean cultivar exceeded Nineveh, Adlib, Baraka and Common Vetch in terms of germination rate (59, 53.6, 40.4 and 124.1%, respectively), Furthermore, it profoundly shortened the days required for peak germination (34.6, 40.4, 19.2 and 51.9%, respectively), days for first emergence (110, 105, 100 and 140%, respectively) and radical: plumule lengths ratio (33.9, 9.3, 21.4 and 33.9%, respectively).Therefore, detected cultivars can be arranged as follow: Mungbean> Baraka> Adlib> Nineveh> Common Vetch. The most effective dual interaction was Mungbean seeds germinated under field capacity. It manifested the best values in terms of final germination rate (100%), germination time (1day), and germination rate (100), plumule length (93.75 mm). It had reduced days required for peak germination (1), days for first emergence (1). Exposing germinated seeds to water stress profoundly altered the differentiation of root components, particularly vessels width and numbers.

*Corresponding Author: Al-Rawi Caser G Abdel ✉ caserabdel@yahoo.com

Introduction

Lentil (Lens culinaris Medik.) is cultivated extensively in rainfed areas of Iraq. However, its yield fluctuated among years. It is also grown in many countries of the Mediterranean region as a cheap source of protein. Lentil is considered as relatively tolerant to drought (Muehlbauer *et al.*, 1985). It is widespread in areas having a mild and warm climate; as relatively high or low temperatures are the most important limiting factors in its cultivation (Saglam et al., 2010). The changes in the contents of the nutrient and non-nutrient substances are influenced by the germination conditions, including the temperature, the presence or absence of light, the composition of the soaking and rinsing media, and the post-germination handling. Leguminous seeds must take up large quantities of water, typically 80–140% of their own weight, if swelling and germination are to occur (Kadlec *et al.,* 2008). Rapid seed germination along with fast germination and seedling emergence substantially contribute to high lentil yield under drought conditions. Seed priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly those of vegetables and small seed grasses (Heydecker and Coolbaer, 1977; Bradford, 1986).

Lack of adequate soil moisture in the seedbed is a major obstacle to the establishment of lentil crop, because inadequate soil moisture can reduce germination, slow down seedling growth and decrease yield in rainfed crops (Sharma and Prasad, 1984). Most commonly the seeds are occasionally sown in seedbeds having unfavorable moisture because of the lack of rainfall at sowing time (Angadi and Entz, 2002), which results poor and unsynchronized seedling emergence (Mwale *et al.*, 2003). In a drying seedbed, priming would clearly aid the germination of seeds sown close to the surface where the soil dries most quickly (Finch-Savage *et al.*, 2005). However, the more rapid germination of the primed seeds may also aid those sown more deeply. This is because the seedbed can deteriorate with time and in general, its negative impact increases with sowing depth and consequent delay in emergence. Increasing impedance can be a major problem under these conditions for maize (Murungu *et al.*, 2004). Ghassemi-Golezani *et al.* (2008) has reported beneficial effects of hydropriming on germination and field emergence of lentil but no report shows the performance of hydropriming under water stress. Higher germination percentage was obtained from primed seeds compared to control seeds. They found no significant difference for germination between primed and unprimed seeds of lentil; as they conducted the experiment under optimum conditions for lentil germination without imposing water stress. Hydropriming showed 90% germination under water stresses, but germination percentage drastically declined and delayed in unprimed seeds. Germination was severely limited to 70% at the highest water stress level of -0.6 MPa (Saglam *et al.*, 2010).They also reported that a three-way interaction was determined for germination percentage (GP), mean germination time (MGT), shoot length (SL), shoot fresh weight (SFW) and shoot dry weight (SDW). Sultan 1 lentil cultivar gave higher germination percentage with 100% germination under all water stresses. Unprimed seeds resulted in lower germination regardless of water stress. Mean germination time increased with an increase in water stress; however, hydropriming shortened it more compared to unprimed. Greater reduction in shoot length of unprimed seeds due to water stress compared to hydropriming was very evident. The longest shoots were obtained from primed seeds of Pul-11 lentil cultivar under all water stresses. Shoot length was severely influenced by water stress while the impact was much smaller in primed seeds compared to root length at all cultivars except for -0.3 MPa; however, this decrease was more prominent at unprimed seeds the respective cultivars (Saglam *et al.,* 2010). Although root length was adversely affected by water stresses, significant and higher enhancement due to hydropriming was very evident. Where, primed seeds gave the longest roots at all types of water stresses. Furthermore, Sung and Chiu (1995) proposed that emergence force and seedling growth were strengthened by hydropriming in watermelon. Resemble results were unveiled by Sadeghian and Yavari (2004) found that seedling growth severely diminished with increased drought stress irrespective of the genetic differences in sugar beet. The aim of this investigation was to evaluate the seed germination performances of common vetch, mungbeans and three lentil cultivars at varying soil water availabilities.

Materials and methods

Factorial Randomized Complete Block Design was used in this experiment where factor (A) contained four soil water availabilities levels where soil at field capacity (100%) water available capacity AWC (a_1), 25% AWC depletion (a_2), 50% AWC depletion (a_3), 75% AWC depletion (a4). Whereas factor (B) was represented by Nineveh lentil cv. (b_1), Adlib lentil cv. (b_2), Baraka lentil cv. (b3), L₀cal Common Vetch cv. (b_4) and Local Mungbean cv. (b_5). Subsequently, 20 treatments were included in this investigation. Every treatment was replicated 4 times and one replicate contained 4 plastic disposable dishes were used to germinate 25 seeds per each.

Dry soil of given weight was distributed in disposable dishes and then saturated and sealed by polyethylene bags, after 24h when free water was completely drained samples were re-weighed and the mean of weight differences was considered as the available soil water capacity (AWC). Water quantities equal to 100, 75, 50 and 25% AWC were mixed with resembles weight of the above soil dry weight and tightly sealed by plastic bags to prevent evaporation. Therefore, these varying moistened levels of soils were considered corresponding to 100% AWC depletion, 25% AWC depletion, 50% AWC depletion, and 75% AWC depletion, respectively.

Duration required for peak germination (days), and days for emergence commencements were counted. Final germination percentage, germination energy percentage were calculated from dividing number of germinated seeds on total seeds and from yield of number of germinated seeds after three days from starting divided on the total seeds, respectively, (Ruan et al., 2002). Germination rate: germination percentage ratio was calculated from dividing the Germination rate over germination percentage. Radical and plumule lengths (mm) were measured by mini roller. While radical Plumule Length ratio was calculated by dividing the length of radical over the length of plumule.

Germination rate (seedling.d-1) was calculated from the following formula (Carleton, 1968): SG = No. of grains emerged at first count / Days of first count + ...+ No. of grains emerged at final count / days of final count. Mean germination time (days) was calculated from the equation below:

$$MGR = \frac{\Sigma nidi}{N}$$

Where ni= number of germinated seeds on day I, d= rank order of day i (number of days counted from the beginning of germinated), and N=total number of germinated seeds. Finally, data were analyzed by computer statistical program, using Duncan's Multiple Range Test at α = 0.05 probability level.

Results and discussion

Soil water availabilities

Seed germination proceeds under field capacity (0 depletion %) was the best. This treatment surpassed over 25, 50 and 75% depletion of AWC in terms of final germination percentage (2.8, 13.3, 53.2%, respectively), germination energy (10.6,28.7 and 90.5%, respectively), germination rate (28.6, 49.4 and 124.7.2%, respectively), germination rate : germination percentage ratio (26.5, 13.7 and 52%, respectively), radical length(16.6, 48 and 129.1 %, respectively), plumule length 27.5, 34.8 and 128 %, respectively, (Table 1, Fig., 1-5). Treatment of 25% AWC depletion comes next in superiority, since it profoundly surpassed that of 50 and 75% AWC depletion in final germination percentage (10.1 and 49%, respectively), germination energy (16.3 and 72.2%, respectively), germination rate (16.1 and 74.6%, respectively), germination rate: germination ratio (5 and 21%, respectively), radical length (26.9 and 96.4%, respectively) and plumule length (5.6

and 787%, respectively). Moreover, it highly shortened the duration required for peak germination (10.8 and 20.4%, respectively) and days required for first emergence (42.1 and 65.7%, respectively). 50% AWC depletion treatment was considered as the third in sequence order. This treatment exceeded that of 75% AWC depletion in final germination percentage (35.2%), germination energy (48%), and germination rate (50.3%), germination rate: germination ratio (15%), radical length (54.7%) and plumule length (69.1%). The 75% AWC depletion displayed the lowest values in terms of final germination percentage (65.25%), germination energy (50.5%), and germination rate (25%), germination rate: germination ratio (0.371), radical length (42 mm) and plumule length (36.5 Anatomical changes in root sections were obvious in cell sizes and vessels performance where water stress was resulted in deformed and small vessels sizes (Fig. 4 and 5).

Table 1a. Seed germination and seedling performances in different cultivars in response to soil water availabilities.

Treatments		Final Germ. (%)	Mean Germ. Time (days)	Germ. Energy (%)	Germ. Rate (seedling/ day)	Days for Peak Germ.
AWC depletion (%)	Control	100a	0.483c	96.25a	56.41a	3.05d
	25	97.25b	0.677a	87.0b	43.839b	4.15c
	50	88.25c	0.569b	74.75c	37.743c	4.6b
	75	65.25d	0.477c	50.50d	25.097d	5.0a
Legume Crops	N	86.875b	0.291bc	72.188c	37.288d	4.375b
	A	88.125b	0.3b	79.375b	38.6c	4.563b
	B	92.188a	0.331b	87.813a	42.231b	3.875c
	Common Vetch	79.688c	0.235c	56.25d	26.45e	4.938a
	Mungbean	91.563a	1.6a	90.0a	59.293a	3.25d
Control	N	100a	0.38d	98.75a	48.375cd	3.5de
	A	100a	0.388d	98.75a	48.75c	3.25de
	B	100a	0.385d	100a	48.65c	3.0e
	Common Vetch	100a	0.26dh	83.75cd	36.275g	4.5bc
	Mungbean	100a	1.0c	100a	100a	1.0f
25% AWC depletion	N	96.25ab	0.325de	75ef	40.375ef	4.0cd
	A	98.75a	0.365de	90.0b	45.675d	4.5bc
	B	100a	0.378d	97.5a	47.9cd	3.5de
	Common Vetch	91.25bc	0.365de	72.5fg	32.025h	4.75ac
	Mungbean	100a	1.95a	100a	53.223b	4.0cd
50% AWC depletion	N	88.75c	0.298df	86.75g	38.35eg	5.0ab
	A	87.5c	0.283dg	80.0de	37.15g	5.0ab
	B	91.25bc	0.323de	86.25bc	40.625e	4.0cd
	Common Vetch	86.25c	0.183fh	53.75h	26.45i	5.0ab
	Mungbean	87.5c	1.763b	85.0bd	46.14cd	4.0cd
75% AWC depletion	N	62.5e	0.163gh	46.25i	22.05j	5.0ab
	A	66.25e	0.165gh	48.75hi	22.825j	5.5a
	B	77.5d	0.238eh	67.5g	31.75h	5.0ab
	Common Vetch	41.25f	0.133h	15.0j	11.05k	5.5a
	Mungbean	78.75d	1.688b	75ef	37.808g	4.0cd

Regression results analysis manifested that all detected traits were linearly correlated to varying moisture availabilities and may be forecasted by the equations, accept that of mean germination time and radical: plumule length ratio which were, respectively, cubically and quadratically correlated to water availabilities and they respectively can be predicted by the equations (Table 2).

Table 1b. Germination and physiological features in different cultivars in response to soil water availabilities.

Treatments		Days for First Emergence	Germ. Rate: Germ. % Ratio	Radical Length (mm)	Plumule Length (mm)	Radical Plumule Length ratio
AWC depletion (%)	Control	1.8c	0.564a	96.25a	83.25a	1.158b
	25	1.9c	0.449b	82.5b	65.25b	1.263a
	50	2.7b	0.427c	65c	61.75c	1.088c
	75	3.15a	0.371d	42d	36.5d	1.175b
Legume Crops	N	2.625b	0.423c	74.668b	59.063b	1.277a
	A	2.563b	0.429c	63.125d	58.125b	1.077c
	B	2.5b	0.455b	81.25a	69.063a	1.196b
	Common Vetch	3.0a	0.322d	69.688c	53.125c	1.319a
	Mungbean	1.25c	0.634a	68.438c	69.063a	0.985d
Control	N	2.0e	0.484c	102.5ab	78.75b	1.302ad
	A	2.0e	0.488c	82.5ef	72.5bc	1.119fh
	B	2.0e	0.487c	105a	92.5a	1.135eh
	Common Vetch	2.0e	0.363g	93.75cd	78.75b	1.191df
	Mungbean	1.0f	1.0a	97.5bc	93.75a	1.039gi
25% AWC depletion	N	2.0e	0.419f	82.5ef	60.0ef	1.378ac
	A	2.0e	0.463cd	7.0h	66.25ce	1.058fi
	B	2.0e	0.479c	93.75cd	68.75cd	1.368ac
	Common Vetch	2.5d	0.351g	87.5de	58.75f	1.423a
	Mungbean	1.0f	0.532b	78.75fg	72.5bc	1.087fi
50% AWC depletion	N	3.0c	0.433ef	73.75gh	62.5df	1.284bd
	A	3.0c	0.425ef	62.5i	58.75f	1.064fi
	B	3.0c	0.445de	72.5gh	72.5bc	1.001hi
	Common Vetch	3.5b	0.307h	62.5i	50.g	1.256ce
	Mungbean	1.0f	0.527b	53.75j	65df	0.834j
75% AWC depletion	N	3.5b	0.355g	40kl	35i	1.145eg
	A	3.25bc	0.345g	37.5kl	35i	1.067fi
	B	3.0c	0.409f	53.75j	42.5h	1.278bd
	Common Vetch	4.0a	0.269i	35l	25j	1.408ab
	Mungbean	2.0e	0.477c	43.75k	45gh	0.987i

Germinating media of inadequate moisture are usually resulted in slow rate of enzymatic activities, low energy generation; slow assimilate transportation, cell division and expansions hindrances. Therefore, lack of adequate soil moisture in the seedbed is a major obstacle to the establishment of lentil crop, because inadequate soil moisture can reduce germination, slow down seedling growth and decrease yield in rainfed crops (Sharma and Prasad, 1984).

Table 2. Regression analysis responses of detected germination parameters to moisture availabilities.

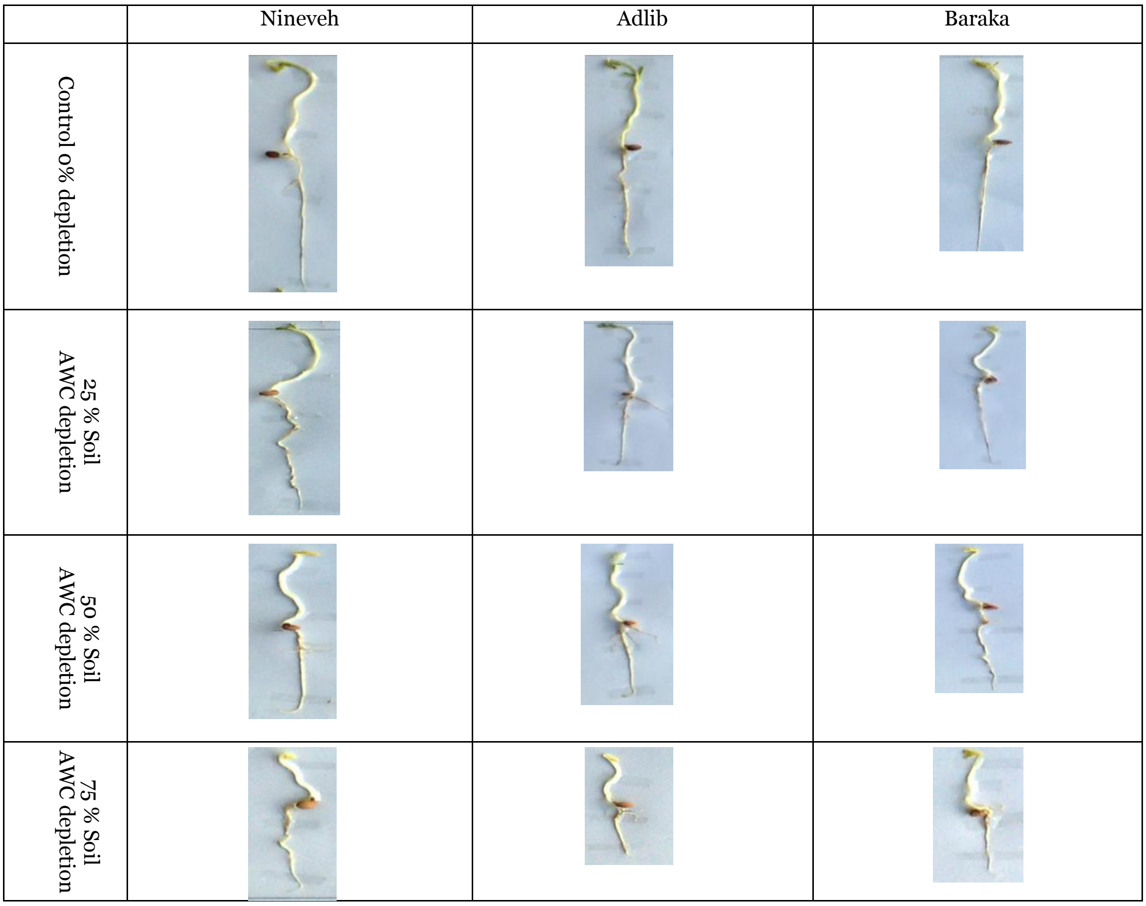
Character	Regression equation	Coeffic.determ. (R^2)
Final Germ. (%)	$Y = 100 – 0.453 X$	64.8
Mean Germ. Time.days	$Y = 0.483 + 0.018 X – 0.0005 X^2 + 0.000003 X^3$	2.1
Germination Energy (%)	$Y = 99.55 – 0.598 X$	56.7
Germ. Rate (seedling/day)	$Y = 55.778 – 0.400 X$	41.9
Days for Peak Germ.	$Y = 3.255 + 0.025 X$	40.2
Days for First Emergence	$Y = 1.66 + 0.019 X$	38.6
Germ. Rate: Germ.%Ratio	$Y = 0.543 – 0.002 X$	21.5
Radical Length (mm)	$Y = 98.475 – 0.721 X$	84.4
Plumule Length (mm)	$Y = 83.25 – 0.575 X$	75.4
Rad. Plum.: Length ratio	$Y = 1.158 + 0.017 X – 0.0007 X^2 + 0.000006 X^2$	13

Cultivar responses

Mungbean cultivar was exceeded Nineveh, Adlib, Baraka and Common Vetch in terms of germination rate (59, 53.6, 40.4 and 124.1%, respectively), germination rate: germination percentage ratio (49.9, 47.8, 39.3 and 96.8%, respectively). Furthermore, it profoundly shortened the days required for peak germination (34.6, 40.4, 19.2 and 51.9%, respectively), days for first emergence (110, 105, 100 and 140%, respectively) and radical: plumule lengths ratio (33.9, 9.3, 21.4 and 33.9%, respectively) (Table 1, Fig. 1-5). The second most significance cultivar was Baraka owing to its prevalence over Nineveh, Adlib and Common Vetch in final germination percentage (6.1, 4.6 and 15.7%, respectively), germination energy (21.6, 10.6 and 56.1%, respectively), and germination rate (13.2, 9.4 and 59.6%, respectively), germination rate: germination ratio (9.1, 7.1 and 18.2%, respectively), radical length (8.8, 28.7 and 16.5%, respectively) and plumule length (16.9, 18.8 and 30%, respectively. Moreover, it highly shortened the duration required for peak germination (12.9, 10.8 and 20.4%, respectively). However, it exceeded Common Vetch only in days required for first emergence (16.6%) and over Mungbean in radical length (18.7%). The third cultivar in the order was Adlib. It exceeded Nineveh in terms of germination rate and germination energy by 3.5 % and 9.9%, respectively. It showed higher values when compared to Common Vetch in final germination percentage (9%), germination energy (41.1%), and germination rate (45.9%), germination rate: germination percentage ratio (33.2%). In addition to that it also reduced days required for peak germination (8.2%), days required for first emergence (17.2%) and radical: plumule lengths ratio (22.5%).

Yet, the lowest values were concomitant with Common Vetch, particularly in terms of final germination percentage (79.7%), germination energy (56.25%), germination rate (26.45%), germination rate: germination percentage (0.322), plumule length (53 mm). In addition to that it also increased days required for peak germination (4.9 days), days required for first emergence (3 days) and radical: plumule lengths ratio (1.3%). Therefore, detected cultivars can be arranged as follow: Mungbean> Baraka> Adlib> Nineveh> Common Vetch. Variation in the responses of cultivars and/or species to water scarcity might be attributed to the nutritional content of individual seeds, particularly, carbohydrates. There are many factors responsible for the depositing of nutrients in seeds for instance, seed location on the mother plant, degree of seed maturity, seed size, embryo performance during embryogenesis and environments. Subsequently, there should be differences within individual seed of the same plant. The changes occurred in the relative content of each type of carbohydrates during the germination of lentil seeds. It shows that the proportion of α-galactosides in the lentil samples decreased from 70% to 25% while, conversely, the sucrose content increased from 22% to 53%, and that of monosaccharide content from 9% to 22% (Kadlec *et al.*, 2008).

Fig. 1. Nature of germination and seedling performances of three lentil cultivars in response to four depletion levels of the soil water available capacities.



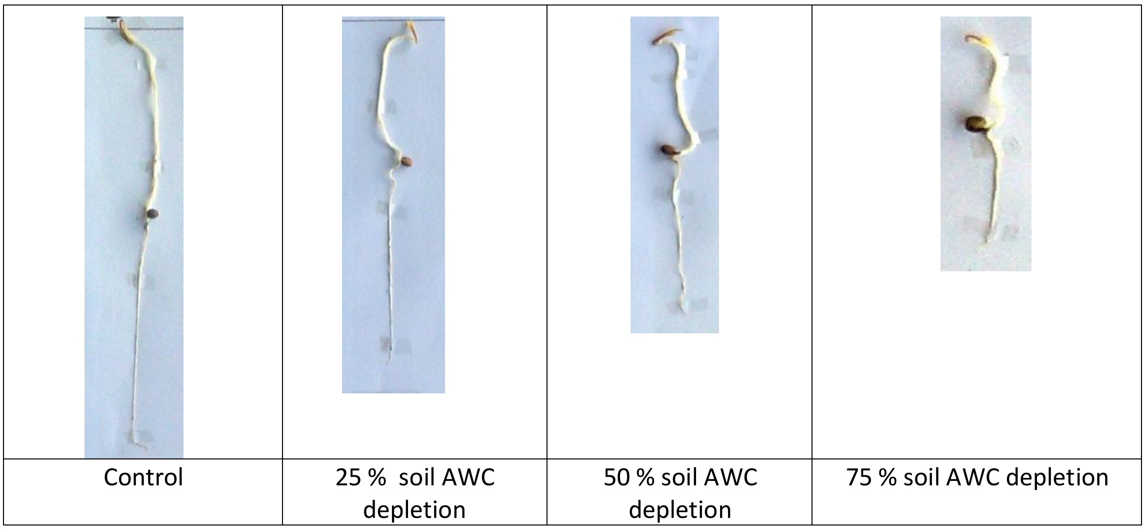


Fig. 2. Nature of germination and seedling performances of Common Vetch in response to four depletion levels of the soil water available capacities.

Control	25 % AWC depletion	50 % AWC depletion	75 % AWC depletion

Fig. 3. Nature of germination and seedling performances of Mungbean in response to four depletion levels of the soil water available.

Kadlec *et al.* also found that reported that the changes took place in the relative content of each type of carbohydrates during the germination of Mungbean seeds. It clearly shows that, over the course of five days of germination, the relative content of α-galactosides in the Mungbean samples decreased from 68% to zero. Conversely, the content of sucrose increased from 22% to 70%, while the monosaccharide contents also increased from 10% to 30%. During five days of germination, the content of raffinose increased from 8% to 32%, the content of both ciceritol and verbascose varied across the range of 18–23%, and that of stachyose decreased from 47% to 30%.

Cultivar responses to water availabilities

The most effective dual interaction was Mungbean seeds germinated under field capacity in final germination rate (100%), germination time (1day), germination rate (100), germination rate: germination percentage ratio (1), plumule length (93.75 mm) (Fig. 3). It had reduced days required for peak germination (1), days for first emergence (1), and radical: plumule lengths ratio (1.039). This treatment displayed the highest values under 75% soil AWC depletion in final germination rate (78.75%), mean germination time (1.688 day), germination energy (75%), germination rate (37.8 seedling.d-1), germination rate: germination percentage ratio (0.477), plumule length (45 mm). It had reduced days required for peak germination (4 days), days for first emergence (2 days), radical: plumule lengths ratio (0.987) (Table 1, Fig. 1-5). Moreover, this treatment showed superiority over others under 25 and 50% AWC depletion in most detected parameters. It is well established that environments creating the gene diversity of individual plant and its speciation. Thus, under severe drought plants switch on their self defense system. These aspects suggested that plants underwent changes preponderated by environment where plant gene diversity was unable to lush those changes. Yet to improve resistance, scientists' subjected seeds to circumstances resemble to that of adversity in order to provoke biochemical changes pre-germination for being recall during germination. The time to seed germination was shortened by hydropriming, probably due to faster water uptake and earlier initiation of metabolism processes (Kaya *et al.,* 2006). Hydropriming showed sharp improvement in both rate of germination and mean germination time under drought stress conditions. The lower mean germination time in unprimed seeds compared to hydroprimed seeds of the cultivars under all levels of water stress could be explained by more rapid water uptake in small seeds for early achievement of necessary moisture content required for germination (Saglam *et al*., 2010).

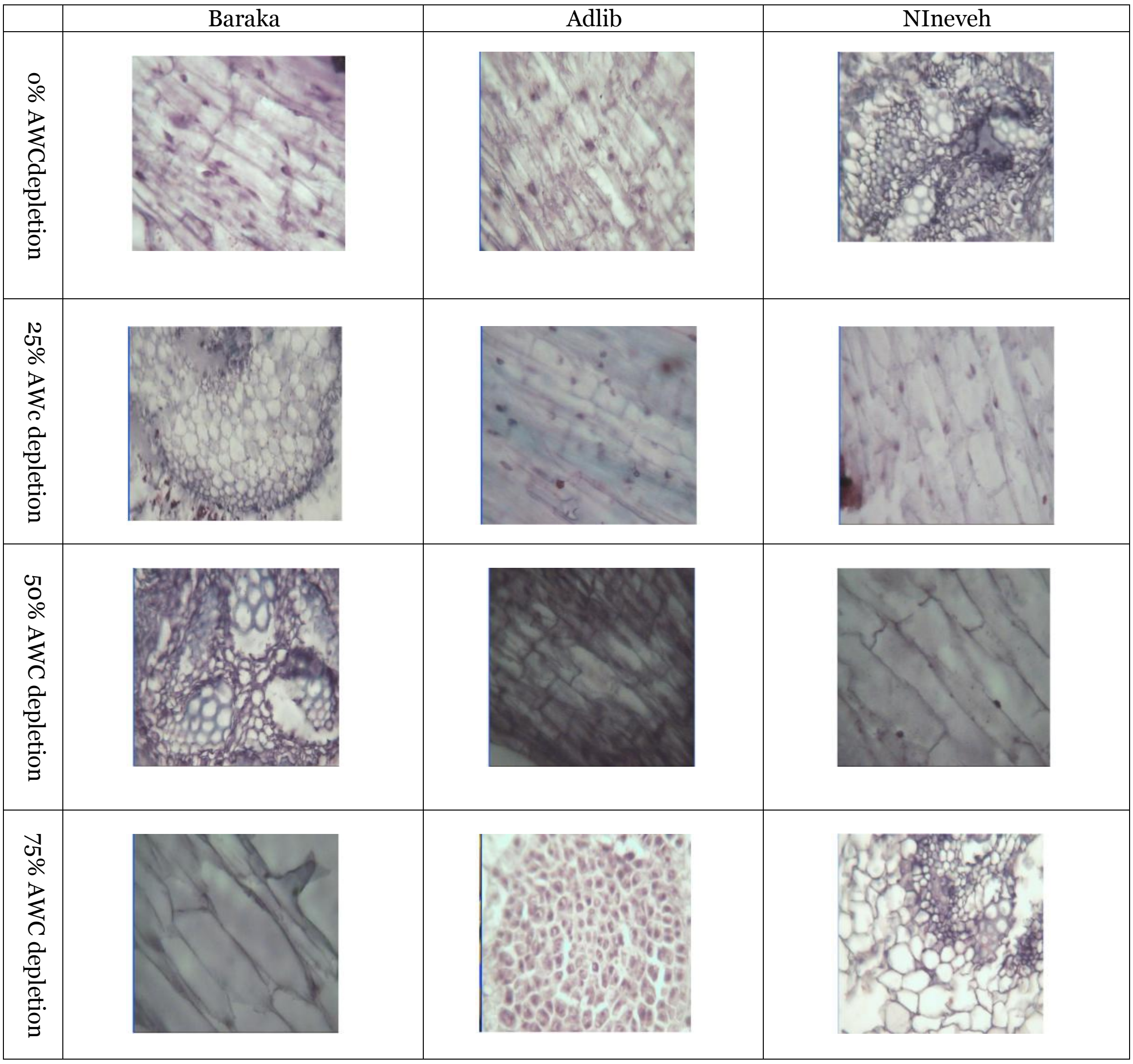


Fig 4. The influence of varying soil water availabilities on root anatomy of three lentil cultivars (Magnification 7X40).

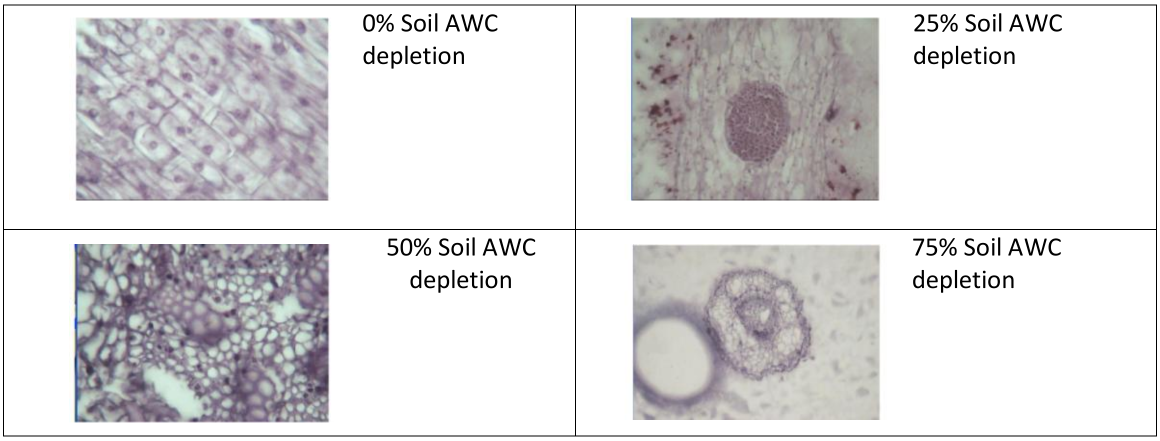


Fig. 5. The influence of varying soil water availabilities on root anatomy of Common Vetch Local cultivar (Magnification 7X40).

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