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Article

MODELING THE EMERGENCE AND GROWTH OF ALLIGATORWEED AT DIFFERENT FIELD CAPACITY LEVELS

Modelando a Emergência e o Crescimento da Erva-de-Jacaré em Diferentes Níveis de Capacidade de Campo

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ABSTRACT - A study focusing on different field capacity levels was planned in the Weed Science Lab, Department of Agronomy, University of Agriculture Faisalabad. Fresh alligatorweed was harvested from the Agronomy fields and cuttings (2 cm length) were made from it. These cuttings were placed at 25%, 50%, 75% and 100% field capacity levels in pots for 25 days. The results of the experiments revealed that at all field capacity levels, fragments of alligatorweed were able to sprout and grow. Increased moisture levels significantly increased the emergence ability and survival of the alligatorweed plants upto a certain level. Compared with the control (25% FC), emergence time of the sprouts in the maximum moisture regime (100% of FC) decreased by 40% (12.94 days vs.7.17 days). By contrast, the survival rate of the fragments decreased by 60% (5 vs. 1.75) although survival and growth rate increased at first with 50% FC and 75% FC. Maximum sprouting and growth were found at 50% field capacity. Field capacity does affect the sprouting capacity of alligatorweed fragments but it has only a little influence on growth parameters. The results suggest that alligatorweed can sustain dry conditions to a great extent and also has the ability to sprout and grow in fully submerged soils.

Keywords: humidity soil conditions, invasive weed, seedling growth.

RESUMO - Foi conduzido um estudo com foco nos diferentes níveis de capacidade de campo no Laboratório de Ciências de Plantas Daninhas do Departamento de Agronomia da University of Agriculture Faisalabad. Erva-de-jacaré fresca foi colhida em campo para a preparação de estacas (2 cm de comprimento). Essas estacas foram mantidas em vasos por 25 dias, em níveis de 25%, 50%, 75% e 100% da capacidade de campo. Os resultados dos experimentos revelaram que, em todos os níveis de capacidade de campo, houve crescimento e brotação dos fragmentos de erva-de-jacaré. A elevação da umidade levou a aumento significativo da capacidade de emergência e sobrevivência das plantas de erva-de-jacaré até um certo nível. Comparado com o controle (25% CC), o tempo de emergência dos brotos no regime de umidade máxima (100% da CC) diminuiu em 40% (12,94 dias contra 7,17 dias). Já a taxa de sobrevivência dos fragmentos diminuiu em 60% (5 contra 1,75), embora a taxa de sobrevivência e o crescimento tenham aumentado inicialmente com 50% de CC e 75% de CC. Os valores máximos de crescimento e brotação foram observados a 50% da capacidade de campo. A capacidade de campo afeta a capacidade de brotação dos fragmentos de erva-de-jacaré, mas tem pouca influência nos parâmetros de crescimento. Os resultados sugerem que a erva-de-jacaré é capaz de suportar bem a escassez de água, assim como consegue brotar e crescer em solos totalmente submersos.

Palavras-chave: condições de umidade do solo, planta daninha invasora, crescimento de plântulas.

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INTRODUCTION

Biotic invasion is considered as one of the top five causes of global biodiversity loss and it is increasing on a daily basis because of tourism and globalization. Invasive species may drive local native species to extinction via competitive exclusion, niche displacement, or hybridization with related native species. Therefore, in addition to their economic ramifications, alien invasions may result in extensive changes in the structure, composition and global distribution of the biota of sites of introduction, ultimately leading to the homogenization of the world's fauna and flora and loss of biodiversity (Odendaal et al., 2008).

Alternanthera philoxeroides, commonly known as alligatorweed, is an emergent invasive weed in Pakistan. Alligatorweed is one of the invasive weeds which poses serious threats to native plant populations and cropping systems throughout the world (Khan et al., 2012). It is a potentially devastating weed that grows in water and on land, affecting both waterways and floodplain areas. It is listed as a weed of national significance in Australia (Reid et al., 2009). Alligatorweed disrupts the aquatic environment by blanketing the surface and hence impeding the penetration of light. Such blanketing can also impede gaseous exchange (sometimes leading to anaerobic conditions) which adversely affects aquatic flora and fauna. It also competes with and displaces native flora alongside rivers and creek banks and in wetlands (Ensbey and van Oosterhout, 2001). It is generally considered a water weed but it can also disrupt terrestrial cropping systems, resulting in reduced yield of all the crops because it competes with crops and releases harmful chemicals, called allelochemicals. Yield losses of 19-60% have been reported as a result of *A. sessilis* and *A. philoxeroides*in field crops(Tanveer et al., 2013a).

Alligatorweed is becoming a potential threat in rice-based cropping systems in Pakistan. Conventional weed control methods such as flooding have proved ineffective to control/suppress the growth of alligatorweed and have resulted in a greater loss of water. To reduce his water loss, different techniques are now being applied, e.g., alternate wetting and drying. However, this change will certainly affect the behavior of alligatorweed, too. Previous studies have addressed the behavior and impact of alligatorweed in aquatic ecosystems, yet very little information is available on its dynamics in terrestrial ecosystems, where there may even be drought conditions as well(Bassett et al., 2012). An understanding of seed germination ecology of weeds can assist in predicting their potential distribution and developing effective management strategies (Tanveer et al., 2013b).

There is a great deal of controversy about the water requirement and behavior of alligatorweed in dry environments. Therefore, the objectives of the present research were to find out which water level in the field favors growth and which level restricts it, and to assess the behavior of alligatorweed under different water management techniques.

MATERIAL AND METHODS

Sandy clay loam soil was collected from experimental fields of the Agronomy Department, UAF, Pakistan. The soil sample were oven-dried for 24 hours at 105 ^{o}C and then weighed. An average was calculated to find out total moisture content. Three oven-dried samples were used to find out saturation percentage, which was estimated by measuring the total volume of distilled water used in making fully saturated paste, and then an average was calculated. The following formula was then used to calculate field capacity:

Field capacity (FC) = Saturation percentage/2

Initial weight of the soil in the plastic pots and the respective water content had been previously determined, hence the current weight of every plastic pot after saturation represents 100%, 75%, 50% and 25% field capacity. Field-grown whole plants of alligatorweed (with almost the same age) were uprooted by using random sampling techniques from fields of the Agronomy Department, University of Agriculture Faisalabad, Pakistan in 2015. Equal-sized cuttings (2 cm) with a single node were made from alligatorweed stems. Pots (15.2 cm top diameter, 11.2 cm bottom diameter and 11.8 cm depth) were used to sow the stem cuttings. CRD (completely randomized design) with four repeats was used to layout the experiment. Ten equal-sized cuttings (2 cm) of field-grown alligatorweed were placed evenly in pots and given field capacity was maintained. Weight was maintained by adding water three times a day (in the morning, noon and evening). The pots were placed in an open environment and daily weather data (day to day) were collected from Agricultural Meteorology Cell, UAF, Pakistan. Mean daily maximum and minimum temperatures recorded were 34.9 °C and 27 °C, respectively. Sprouting count was recorded daily. Twenty-five-day-old seedlings were uprooted and washed with water and their shoot, root lengths and fresh weights were recorded. Than plants were dried in an electrical oven for 48 hours at 70 °C and afterwards dry weight of the plants was noted.

Parameters recorded on alligatorweed sprouting and seedling growth were sprouting percentage (SP) (AOSA, 1990), sprouting index (SI) (AOSA, 1990), mean sprouting time (MST) (Ellis and Roberts, 1981), time to 50% sprouting (Coolbear et al., 1984), root length per plant (cm), shoot length per plant (cm), shoot dry weight per plant (mg), root dry weight per plant (mg), seedling dry weight per plant (mg), seedling vigor index (SVI) and root-shoot ratio (RSR).

Procedures for recording observations of lab experiments

Sprouting percentage was determined by counting daily sprouting up to twenty-five days. After this period, observation was concluded. Sprouting was observed daily according to the AOSA methods (1990) and converted into sprouting percentage by the following formula (Equation 1):

$$SP = \frac{\text{Sprouted cuttings}}{\text{Total cuttings}} \times 100 \qquad \text{(eq. 1)}$$

Sprouting Index (SI) was calculated by using the formula (Equation 2) as described by AOSA (1990):

$$SI = \frac{\text{No.of sprouted cuttings}}{\text{Days of first count}} + \cdots + \frac{\text{No.of sprouted cuttings}}{\text{Days of final count}} \qquad \text{(eq. 2)}$$

Mean sprouting time was calculated according to the equation of Ellis and Roberts (1981).

$$MST = \frac{\sum Dn}{\sum n} \times 100 \qquad \text{(eq. 3)}$$

where n is the number of cuttings that had sprouted on day "D" and D is the number of days counted from the beginning of sprouting. Time to 50% sprouting (T_{50}) was calculated according to the formula (Equation 4) of Coolbear et al. (1984)

$$T_{50} = t_i \frac{(N+1/2 - n_i)(t_j - t_i)}{(n_j - n_i)} \qquad \text{(eq. 4)}$$

as modified by Farooq et al. (2005) (Equation 5).

$$T_{50} = t_i \frac{(N/2 - n_i)(t_j - t_i)}{(n_j - n_i)} \qquad \text{(eq. 5)}$$

where N is the final number of sprouted cuttings and n_j and n_i are the cumulative number of cutting sprouted by adjacent counts at times t_j and t_i, respectively, where $n_i < N/2 < n_j$. Sprouting energy (SE) is the percentage of sprouted cuttings as recorded on the 4th day after sowing, relative to the total number of cuttings which were sown (Ruan et al., 2002).

Seedling growth parameters

The survived plants were uprooted from each pot under wet conditions. Shoot length is determined from the root-shoot junction to the top of the seedling. Then average shoot length was determined. The separated roots were taken and their lengths were measured in cm. Then average root length was calculated. After that, the separated roots/shoots of all seedlings were oven-dried at 70 °C for 48 h and then weighed. This weight was used to calculate average root/shoot dry weight per plant in grams. Shoot and root dry weights of all seedlings from each treatment were summed and then used to calculate average seedling dry weight. Sprouting percentage and seedling length were used to calculate seedling vigor index (SVI) by the following formula (Equation 6) as described by Orchard (1977):

$$\text{SVI} = [\text{seedling length (cm)} \times \text{sprouting percentage}] \qquad \text{(eq. 6)}$$

Statistical analysis

The average data collected in this study were analyzed statistically by using Kruskal-Wallis One-Way analysis of variance techniques with computer software Statistix 8.1. The Kruskal-Wallis all-pairwise comparison test was applied at 5% probability level to test the significance of treatment means. The experiment was repeated twice. A simple linear regression model was used to check the effect of burial depths on sprouting and seedling growth response of alligatorweed.

RESULT AND DISCUSSION

Effect of different percentages of field capacity levels (FCL) on alligatorweed sprouting parameters

FCL percentage significantly affected sprouting and survival characteristics of alligatorweed (Table 1). At first, increased FCL enhanced the survival and sprouting of alligatorweed, as shown in (Figure 1A, B, C, D) and (Figure 2A, B, C, D). In the 26 day testing period, maximum final sprouting count (10) (Figure 1c) was recorded at 50% field capacity (FC) followed by that of 75% FC, with a sprouting count of 7.5. Minimum sprouting was recorded at 100% FC.

FCL significantly affected time to start sprouting (Figure 1d). Maximum time taken to start sprouting (7.5 days) was recorded at 25% FC while minimum time (2.75 days) was recorded at 50% FC. Maximum T_{50} (13.52 days) was recorded with 25% FC followed by that of 100% FC (6.75 days), 75% FC (76.36 days) and 25% FC(4.82 days) (Figure 1B). Minimum mean sprouting time (Figure 1A) was recorded at 50% FC (5.9 days), which was statically similar to the mean sprouting time recorded for 100% FC(7.17 days) and 75% FC (7.57 days). As far as sprouting index (Figure 2A) and percentages (Figure 2B) are concerned, there were significant differences between all the treatments. Maximum EI (2.06) and EP (100) were recorded when alligatorweed was grown at 50% FC, followed by growth at 75% FC, 25% FC and 100% FC, respectively.

Effect of field capacity water content percentages on alligatorweed seedling growth

(Figure 3A, B) and (Figure 4A, B, C, D) showed seedling growth response of alligatorweed to different field capacity (FC) percentages. FC percentages significantly affected all the seedling

Table 1 - Analysis of variance for all the study parameters

Parameter	Degree of freedom	Sum of squares	Mean sum of squares	Calculated F value	Probability value
Sprouting Energy	3	262.625	87.5417	23.9	0.00000
Sprouting Index	3	288.5	96.1667	22.6	0.00000
Sprouting Percentage	3	308.375	102.792	52.2	0.00000
Mean Sprouting Time	3	238.5	79.5	9.45	0.00180
Root Dry Weight	3	287.375	95.7917	22.3	0.00000
Root Fresh Weight	3	291.5	97.1667	24.3	0.00000
Root Length	3	221.5	73.8333	7.51	0.00430
Root Shoot Ratio	3	62.5	20.8333	0.9	0.46840
Seedling Dry weight	3	300.875	100.292	31.6	0.00000
Shoot Fresh Weight	3	312.5	104.167	46.3	0.00000
Shoot Dry Weight	3	312.5	104.167	46.3	0.00000
Shoot Length	3	243	81	10.1	0.00130
Seedling Vigor index	3	283.5	94.5	20.3	0.00010
Time to 50% Sprouting	3	266.625	88.875	15.6	0.0002
Total Sprouting	3	308.375	102.792	52.2	0.00000
Time to Start Sprouting	3	251	83.6667	13.4	0.0004

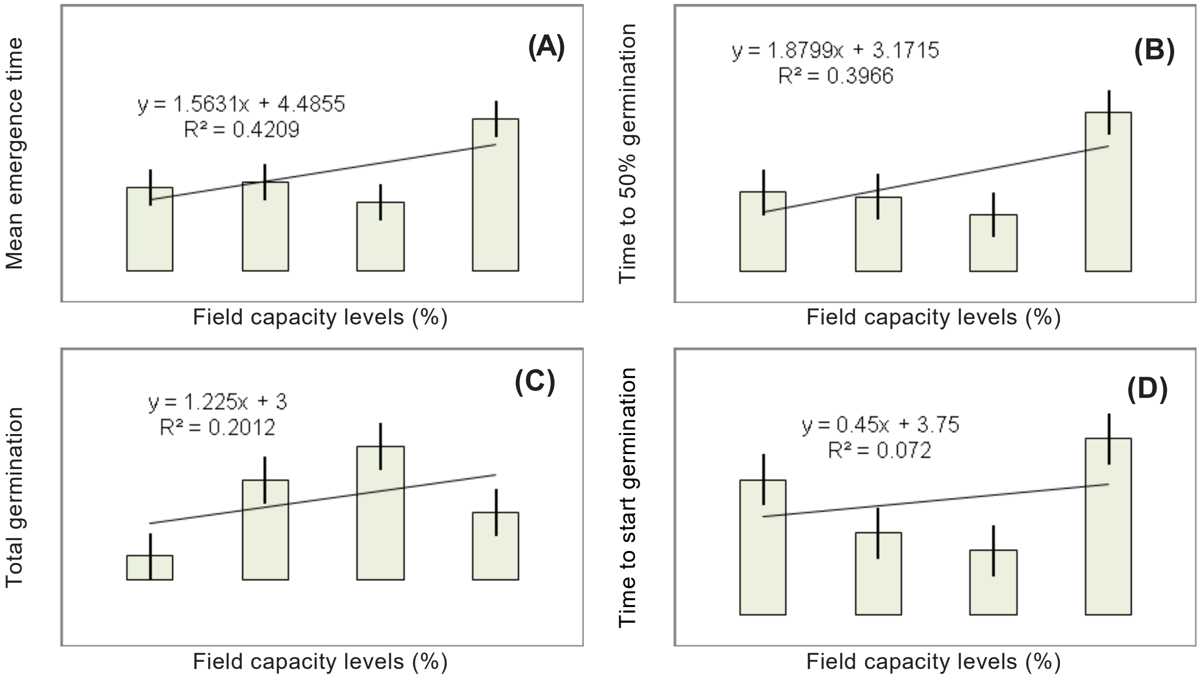

Figure 1 **-** Means of emergence parameters of alligatorweed by different field capacity levels.

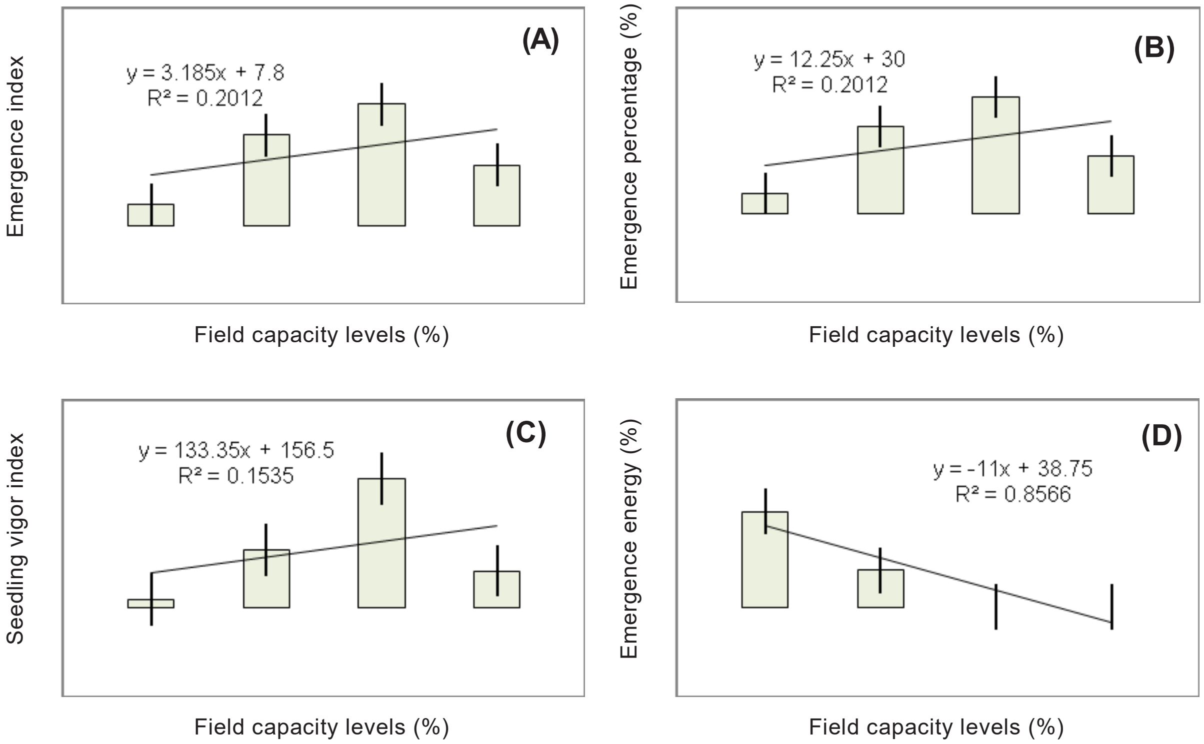

Figure 2 **-** Means of emergence parameters of alligatorweed by different field capacity levels.

growth parameters apart from root-shoot ratio (Table 1; Figure 4D). Maximum shoot length (4.23 cm) was recorded for 50% FC, which was statically higher than all other treatments (Figure 3A). This was followed by the shoot length value recorded for 75% FC (3.21 cm). Minimum shoot length (1.13 cm) was found at 100% of FC. Similar results were found for root length (Figure 3B), root dry weight (Figure 4b), seedling dry weight (Figure 4C) and shoot dry weight (Figure 4A). Seedling vigor index was also higher for 50% FC (1095.1) followed by the seedling vigor index recorded for 75% FC (490) and 25% FC (309).

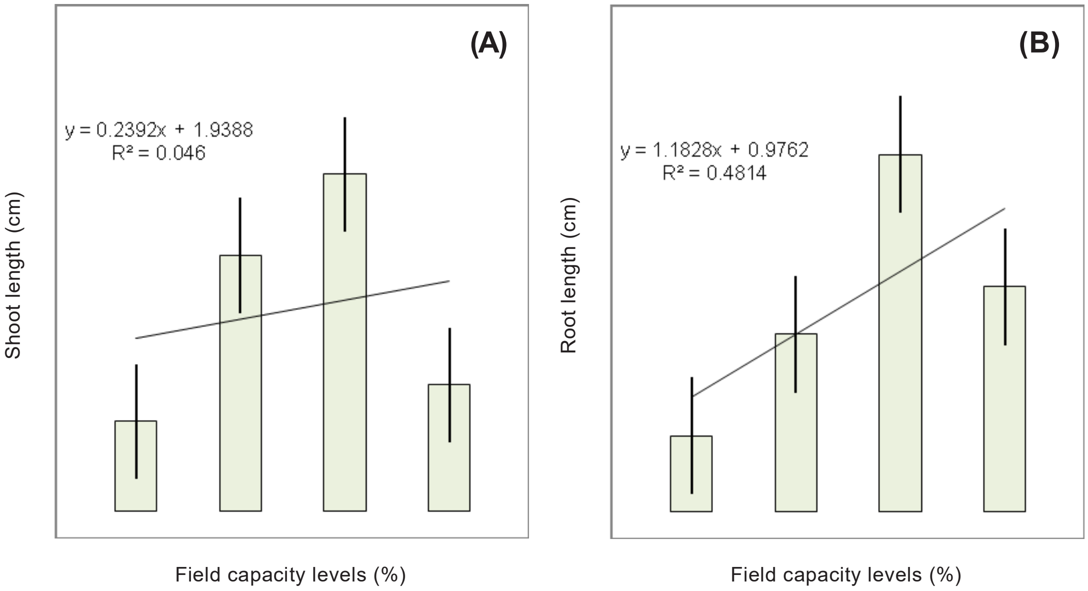

Figure 3 **-** Means of seedling growth of alligatorweed by different field capacity levels.

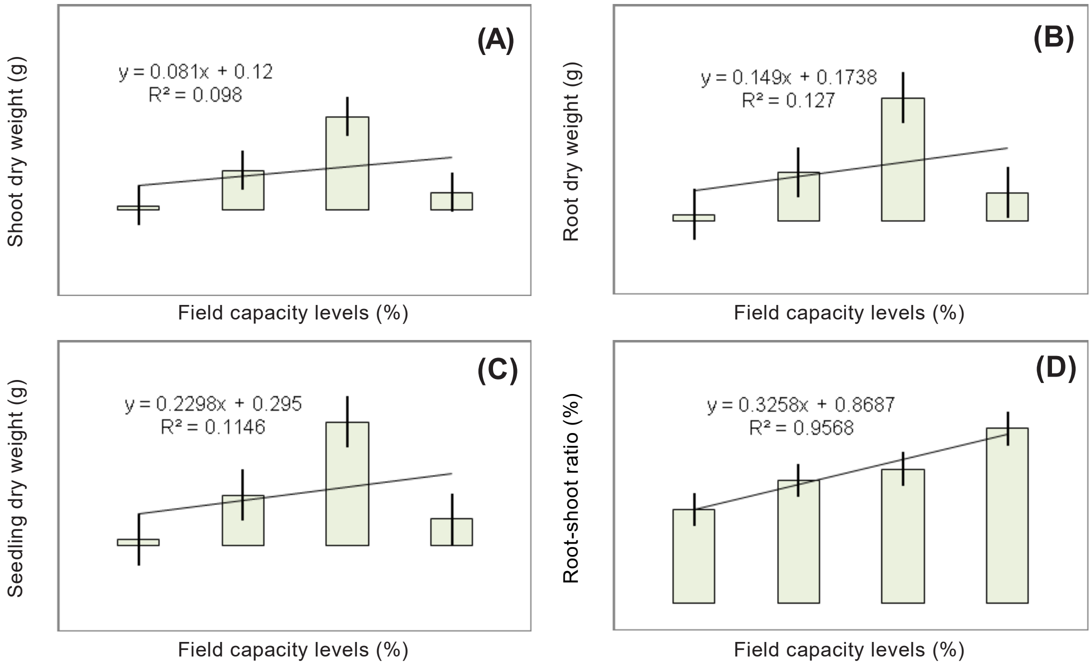

Figure 4 **-** Means of seedling growth parameters of alligatorweed by different field capacity levels.

Increased moisture levels significantly increased the sprouting ability and survival of the alligatorweed plants up to a certain level. Compared with the control (25% of FC), sprouting time of the clonal fragments in the maximum moisture regime (100% FC) decreased by 40% (12.94 days vs 7.17 days). However, the survival rate of the fragments also decreased by 60% (5 vs. 1.75) although survival and growth rate increased at first with 50% of FC and 75% of FC. Previous studies also found that an increase in moisture regime increased the sprouting and survival of *Amaranthus spinosus* and *Leptochloa chinensis* (Chauhan and Abugho, 2013). They conducted trails on water stress treatments (12.5%, 25%, 50%, 75%, and 100% field capacity) and found that both weed species survived in all the treatments. Both weed species produced a significant number of tillers/branches and leaves even at the lowest soil water content. Soil water content to achieve 50% of the maximum aboveground biomass was 47% - 50% field capacity for rice, but 39% and 31% field capacity for *A. spinosus* and *L. chinensis*, respectively.

Quackgrass and foxtail barley had significantly greater sprouting when moisture levels remained between FC and one-third of the FC than when they fluctuated between FC and one-sixth of the FC (Boyd and van Acker, 2003). The impact of soil moisture on sprouting varies among weed species, and field conditions may differ spatially and temporally, depending on rainfall, temperature and soil type. Plant-available water in the soil lies between field capacity (-0.03 MPa) and permanent wilting point (-1.5 MPa) (Miller and Donahue, 2004). Sprouting of *T. portulacastrum* decreased by decreasing field capacity. Decreased sprouting under low moisture conditions was probably due to lack of enough water for seed imbibitions and softening (Tanveer et al., 2013c).

Field capacity actually affects the sprouting capacity of alligatorweed stolons but it has only little influence on RSR, which shows very little effect of FC on growth parameters of alligatorweed. One possible explanation for the irresponsiveness of the species to field capacity is that alligatorweed quickly comes out of soil and starts to transpire as much water as it can, hence itshows no difference at almost at all levels. Late-sprouted plants may enhance the photosynthesis rate by compensating for the water loss which results from delayed sprouting time (Lu and Ding, 2009). Dissimilar plant compensatory capacity, affected by flooding, may explain the different biological control efficacy of alligatorweed in aquatic and terrestrial habitats. Submergence decreased the growth of alligatorweed but allowed 100% survival. Because of increased shoot length when the plants were submerged at the 0.5 m depth for 2 weeks, 62.5% of themgrew above the water (Fan et al., 2015). Elongation of shoots and internodes, higher specific leaf area ratio, leaf weight ratio and stem diameters, development of new leaves (not at depths deeper than 1.0 m) and adventitious roots at all water depths were tolerance strategies of alligatorweed in response to submergence, infect short periods of drying in-between complete flooding may enhance its growth rather than complete flooding or complete drying.

These strategies suggest that alligatorweed can bear significantly high levels of water stress and can survive even at lower field capacity levels. This may increase the invasiveness of alligatorweed and make it very adaptable to heavily disturbed habitats. Based on all these results, it can be concluded that alligatorweed will spread rapidly under the current climatic conditions of Pakistan and will cause greater yield losses in all the crops.

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