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OPTIMIZATION OF WATER AND DIFFERENT ORGANIC/INORGANIC FERTILIZERS TO DETERMINE THE GROWTH OF *VACHELLIA NILOTICA* AND *BOMBAX CEIBA* SEEDLINGS

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Abstract

Vachellia nilotica and *Bombax ceiba* are multipurpose tree species being used in different agroforestry systems and irrigated forest plantations. Both are commonly used as source of tannin, gum, timber, medicine, and fuelwood etc. Scarcity of water and low soil fertility are major problems in arid to semiarid regions of Pakistan, resulting in reduced crop and forest yield. It can be rectified by applying optimal doses of organic and inorganic fertilizers with best irrigation levels. The effect of farmyard manure (FYM), nitrogen, phosphorus and potassium (NPK) fertilizers along with irrigation levels were compared on the seedling growth *V. nilotica* and *B. ceiba* at the research station of Department of Forestry and Range Management, University of Agriculture Faisalabad, Pakistan. Different doses of NPK and FYM (T_0 = Control, T_1 = NPK_2, T_2 = NPK_1, T_3 = NPK_2+ FYM_2, T_4 = NPK_2+ FYM_1, T_5 = NPK_1+ FYM_2, T_6 = NPK_1+ FYM_1) were applied with two irrigation levels, and water was applied at fixed intervals i.e., 7 and 14 days. It was concluded that maximum growth response of morphological (height, diameter, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, total biomass, moisture content availability) and physiological parameters (transpiration rate, photosynthetic rate, stomatal conductance) were recorded at T_6 (maximum irrigation and fertilizer levels), with 7 days irrigation interval and minimum response was recorded at T_0 (minimum irrigation and fertilizer levels). Furthermore, the findings of study highlighted the necessity of organic and inorganic fertilizers in improving the biomass of tree species for reducing the rotation age in agroforestry systems.

INTRODUCTION

Availability of water with inherent soil fertility are important factors determining the growth and plant yield (Lenka *et al*., 2009). Important nutrients that play a critical role in the growth and development of trees at different growth stages are nitrogen (N), phosphorus (P), potassium (K) along with other micronutrients (Lambers *et al*., 2008). In arid to semi-arid regions of the world, limited availability of water and nutrients are two important factors responsible for the reduced crop and forest productivity (Brady, 2015). Due to

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diverse climatic and edaphic conditions, Pakistan is rich in biodiversity but limited availability of nitrogen and phosphorous in the soil is considered responsible for retarded plant growth (Wilson *et al*., 2005). Nitrogen is more mobile compared to phosphorus, and thus has more spatial and temporal distribution (Srivastava *et al*., 2017). Further, nitrogen rapidly assimilates into proteins or amino acids, which are major nitrogen accumulation compounds in plants (Van Rees *et al*., 2002; Chapin *et al*., 2016).

Water scarcity is considered one of the most limiting factors responsible for less agricultural yield in Pakistan. The most effective technique for getting maximum yield in arid to semi-arid conditions is the conservation of available moisture. Low organic contents and high temperature in arid areas of Pakistan during summer reduce the moisture contents which have negative impact on the plant growth (Sarwar *et al*., 2008). The objective of irrigation is to maintain the optimum water level that enhances the production within the limited supply of irrigation water. (Woldeab, 2003).

In Pakistan, organic contents of the soils is very low and exert negative effects on plant growth. Integrated use of organic and inorganic fertilizer may overcome the nutrient deficiencies and can enhance plant growth because higher organic contents in the soil retain moisture and conserve nutrients, so the moisture depletion rate, decreases with the increase of organic manure (Sarwar, 2005). Compost is considered a major source that can overcome nutrient deficiencies, increase organic contents and ultimately improves soil texture and structure (Zia *et al*., 1998; Marenya and Barrett, 2007).

Micronutrients released from organic fertilizers also have a sustainable effect on the growth and development of the crop (Khybri *et al*., 2005). Farmyard manure is helpful in minimizing soil salinity and may increase physiological growth and maximize the grain yield of crops (Cha-Um *et al*., 2011; Zhao *et al*., 2016). Farmyard manure is heterogeneous and is composed by the decomposition of organic material present in dung, crop residue, and household waste (Singh *et al.,* 2009).

Low soil fertility and accessibility of inorganic fertilizers due to high charges are two major biophysical constraints in the uplift of agroforestry practices (Farhad *et al*., 2011). Organic manures are important for improving soil quality and crop yield as they perform several functions in agro-ecosystems (Alabadan *et al*., 2009). Major organic sources of nutrients include farmyard manure mainly generated from sheep and poultry farms, and also comes from green manures and sewage sludge (Iqbal *et al*., 2014).

The development of multipurpose fast-growing tree plantations in tropical, subtropical and temperate regions of the world is increasing to meet the world's exploding population's demand for timber and fuelwood. Agroforestry and compact forest plantations can help to mitigate climate change in forest-depleted regions like Pakistan by reducing pressure on of natural forests (Meagy *et al*., 2016). Because of the food security issues, producers are motivated to restore soil health by applying various fertilizers and manures for improving crop growth and yield (Stamford *et at*., 2007). Trees play an important role in maintaining the ecological balance. Raising of different tree species are being promoted

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on different sites like farmlands, as linear plantations along road and canal sides for the conservation of biodiversity and environmental protection (Ajayi, 2007; Abebe, 2007).

Among these *V. nilotica* is a well-known and valuable agroforestry tree species in the Mimosaceae family. Individuals use almost every component of the tree. Its seeds yield cooking oil, which can be used in place of cotton seed oil (Witt *et al.*, 2005, 2006). The species can be used to make paper and has pulping qualities similar to those of other tropical timbers. The wood of *V. nilotica* has a high calorific value of 4950 kcal/kg, making it an excellent fuel and charcoal wood.

B. ceiba is a deciduous tree commonly known as Semal or Silk red cotton, belongs to the Bombacaceae family. It is native to Pakistan, India and is also found in Sri Lanka, Bangladesh, Malaysia and Northern Australia. Being a multi-purpose and fast-growing tree, it is also found in different regions of the world (Jones *et al*., 2007). This tree is also valuable for controlling soil erosion. Young branches and leaves are looped for feeding and the roots are eaten as sweet potatoes (Iqbal *et al*., 2014). The objective of the study was to estimate the different doses of organic and inorganic fertilizers and water levels for improving the biomass and growth of *V. nilotica* and *B. ceiba*.

MATERIAL AND METHODS

Description of study site

Experimental area of the Department of Forestry and Range Management is situated at 31º 25'57" N and 73º 04' 21" E. Faisalabad receive less rainfall and normally has semi-arid climate. The average high and low temperatures in June are 40.5 °C and 26.9 °C, respectively. January average low and high temperatures ranges from 4°C to 19°C, respectively. A local meteorological station installed at University of Agriculture Faisalabad, was used to collect climate data during the research period.

For raising the seedlings of *V. nilotica* and *B. ceiba* beds with dimensions (10 *3 feet) were prepared with the help of spades and shovel. Healthy and viable seeds of both species were collected from Punjab Forestry Research Institute Gatwala, Faisalabad. Polythene tubes (22.5 *10 cm) were used for producing seedlings. Before filling the polythene tubes with soil, holes were made in the tubes for watering and aeration. Then after applying pre sowing treatments seeds were sown in the tubes and after four months seedlings were ready for the experiment. Seedling having similar size and mass with no apparent disease or stress were selected for the trial. Selected seedlings were shifted in earthen pots of size (30 cm) before transferring, the pots were filled with fine quality soil. Seedlings were allowed to settle in earthen pots for one month. After that NPK (nitrogen, phosphorous and potassium) and FYM (farmyard manure) levels were developed in respective treatments by applying calculated amount of fertilizers and manure. Seven treatments were developed, T_0 was considered as control as there was no addition of NPK and FYM but in rest of the treatments fixed amount of these fertilizers were applied. For all treatments two irrigation levels were used and water was applied at fixed intervals

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i.e., 7 days and 14 days. Treatments were replicated two times with two irrigation levels for each species. Data was statistically analyzed and interpreted by using Minitab, Statics 8.1, and GraphPad Prism in three factorials under RCBD. There were seven treatments including control (T_0 = Control, T_1 = NPK_2 =140 g, T_2 = NPK_1 =280g, T_3 = NPK_2+ FYM_2 =330g, T_4 = NPK_2+ FYM_1 =420 g, T_5 = NPK_1+ FYM_2 =470 g, T_6 = NPK_1+ FYM_1 =560 g) with two replications and irrigation levels.

Table 3.1: Chemical and Physical properties of soil

Parameters	0-15 cm	15-30 cm
pH	7.92	7.98
EC (dSm^{-1})	1.61	1.31
TSS (ppm)	1150	1221
Nitrogen (%)	0.070	0.05
Phosphorous (ppm)	3.5	9.3
Potassium (ppm)	270	240
Organic matter (%)	1.45	0.78
Sand (%)	42	71
Silt (%)	46	17.90
Clay (%)	14	11.5

Measurements of Morphological and Physiological Parameters

Visible characteristics like structure of the plants, shape and size were studied as the main elements to evaluate the positive effect of water and fertilization. These aspects directly affect the entire composition of the plant parts. Different morphological parameters were studied during trial.

A digital caliper was used to measure diameter for seedlings and plants height was measured by using measuring tape. At the completion of trial plants (seedlings) were harvested for the fresh weight of roots and shoots. Root fresh weight was measured by electrical weighing balance (Electronic Scale JJ3000B).

The root and shoots of the plants were separated and put into paper bags for sun drying after taking fresh weight. After sun drying those bags were placed in an electric oven (DGH – 9202 series thermal electric thermostat drying oven) at a temperature of 70 °C and constant weight was achieved. To calculate the total biomass produced in each treatment a sum of (Leaves, stem, and root) was used. Moisture contents availability (MCA) was calculated by the following formula.

$$\mathrm{MCA} = \frac{\text{Total fresh weight} - \text{Total dry weight}}{\text{Total fresh weight}} \times 100$$

Average moisture contents availability was calculated for different replications and treatments.

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The science of plant physiology is one that focuses primarily on how plants work. It entails the investigation of several basic biological processes, including respiration rate, stomatal conductance, photosynthetic rate etc. The IRGA, LCA-4, Analytical Development Company, Hoddesdon, UK, was used to measure respiration rate, stomatal conductance, photosynthetic rate.

The rate of photosynthesis is a gross measure of the rate at which a plant captures radiant energy and fixes it in organic carbon compounds. Because CO_2 concentrations in the atmosphere is low (approximately 0.04%), every increase in CO_2 concentration results in a sharp increase in the rate of photosynthetic activity.

The transpiration rate is a plant activity in which water movement take place through their aerial components, such as stems, branches, leaves, and flowers, which absorbed via their roots. IRGA, LCA-4, Analytical Development Company, Hoddesdon, UK, was used to measure transpiration rate.

Based on the size of the stomatal aperture, stomatal conductance represents rate of exchange of gases (i.e., CO_2 absorption) and transpiration rate from leaf stomata.

RESULTS

This study indicated that almost all the growth parameters showed better results when treated with organic and inorganic fertilizers and irrigation levels compared to control. Different morphological parameters of *V.nilotica* and *B.ceiba* species against different water stress and fertilizer levels are presented in Fig. 1. , it can be observed that mentioned parameters of *V. nilotica*. And *B.ceiba* were significantly different from each other in all treatments ($p<0.005$), similarly the interaction between irrigation and treatments exhibited almost similar results ($p=0.005$).

Plants height, plant diameter, root fresh weight, shoot fresh weight, root dry weight, shoot dry weight, biomass, and moister content availability of selected tree species against all the treatments were recorded. The plant height of selected two species was found in the range of 22.61-35.37 cm (fig. 1a).

The stem diameter of *V. nilotica* and *B. ceiba* against different treatments was recorded in the range of 2.85-3.42 mm (fig.1b). The root fresh weight and shoot fresh weight of both species was recorded 471.49-594.50 gm (fig. 1c), 431.28-750.75 gm (fig.1d) respectively.

The root dry weight, shoot dry weight, total biomass and moisture content availability were found in the range of 341.66-394.81 gm (fig.1e), 312.52-486.15gm (fig.1h), 654.18-880.96 gm (fig.1f) and 34.51-37.53% respectively. Overall growth response of *V. nilotica* was higher as compared to *B. ceiba* at the seedling stage but general trend for both species under all treatment was noted as ($T_1 < T_2 < T_3 < T_4 < T_5 < T_6$).

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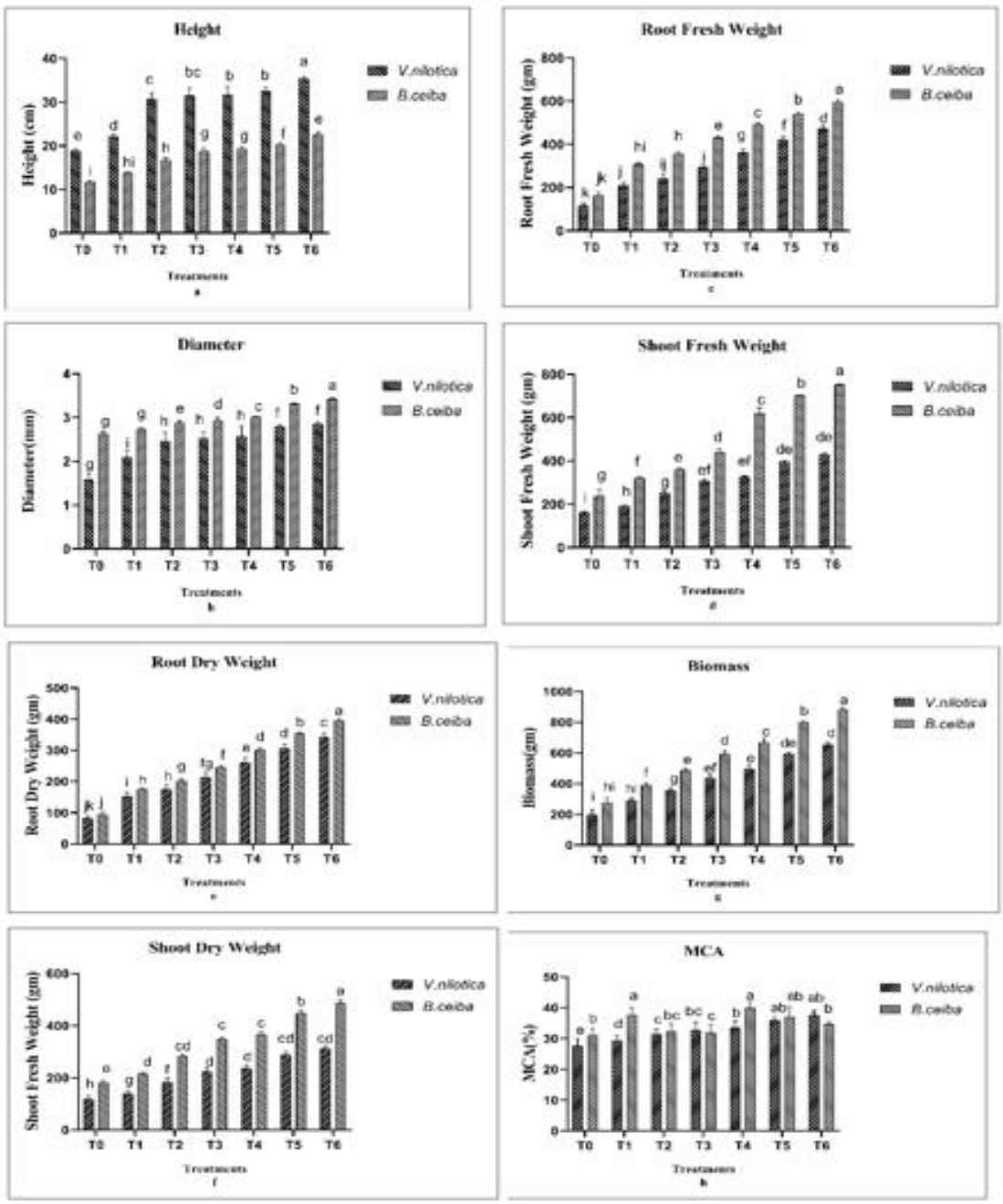

Fig 4.1: Effect of organic and inorganic amendments on (a) Plant height, (b) Plant diameter, (c) Root fresh weight, (d) Shoot fresh weight, (e) Root dry weight, (f) Shoot dry weight, (g) Biomass and (h) Moisture content availability (MCA) of *V. nilotica* and *B.ceiba* at seedling stage.

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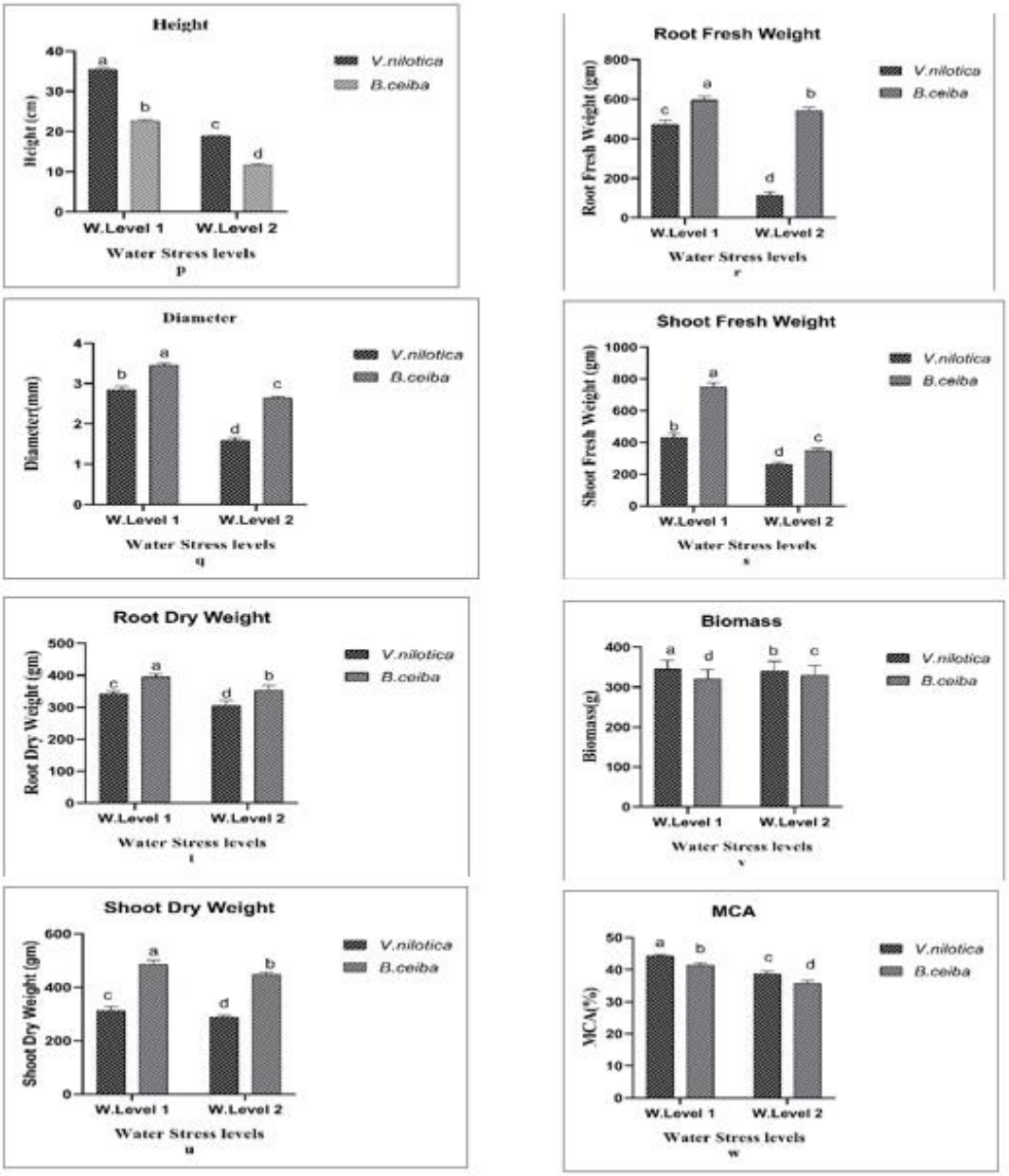

Fig 4.2: Effect of different water stress levels on (l) Plant height, (m) Plant diameter, (n) Root fresh weight, (o) Shoot fresh weight, (p) Root dry weight, (q) Shoot dry Weight, (r) Biomass and (s) Moisture content availability (MCA) of *V. nilotica* and *B.ceiba* at seedling stage.

Several physiological parameters have been used as quantitative indicators of plant health during abiotic stresses, including stomatal conductance, photosynthetic and transpiration rate. Physiological parameters: Fig.4.3. Showed the results of different physiological parameters against treatments. The transpiration rate of selected tree

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species was recorded from the range of 13.62-21.67 mmol H_2O m-2s-1(fig.2a). Similarly photosynthetic rate and stomatal conductance of *V. nilotica* and *B. ceiba* was recorded in the range of 2.48-9.71 µmol CO_2 m-2s-1(fig.2b), and 0.3-0.22 mol m-2s-1 respectively. Overall growth response of *V. nilotica* was higher as compared to *B. ceiba* at the seedling stage but general trend for both species under all treatment was noted as ($T_1 < T_2 < T_3 < T_4 < T_5 < T_6$).

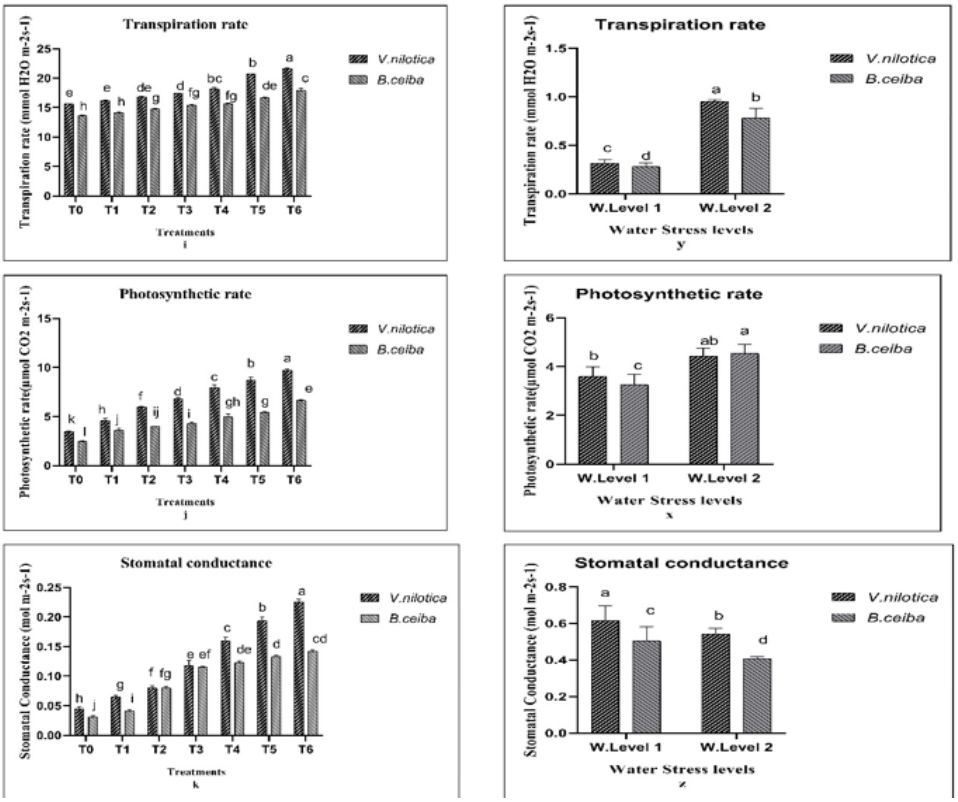

Fig 4.3: Effect of organic and inorganic amendments with different irrigation levels on (i,y) Transpiration rate, (j,x) Photosynthetic rate, (k,z) Stomatal conductance of *V. nilotica* and *B.ceiba* at seedling stage.

DISCUSSION

The results of current experiment showed that, fertilizer application and varying moisture levels considerably accelerated the growth of selected agroforestry tree species at seedling stage. In comparison to control conditions, maximum doses of fertilizers and irrigation resulted in larger shoot and root weight computed based on morphological criteria such as root and shoot length, number of leaves, stem diameter, plant height, total biomass, moisture content availability, root fresh and dry weight similarly shoot fresh and dry weight. The results of present research are similar to different findings (Sarwar, 2005; Brown and Petrie, 2006). Soil moisture and nutrients are two principle factors affecting

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plant growth especially at seedling stage followed by sapling and pole stages (Hossain *et al*., 2000; Sarwar *et al*., 2008; Lenka *et al*., 2009; Marenya and Barrett, 2007; Dong *et al.*, 2011). The simultaneous application of irrigation and nutrients enhanced growth of different tree species at different growth stages (Grigal, 2000; Nasim *et al*., 2012; Wang *et al*., 2015; Brady, 2015). Deficiency of irrigation affected different physiological mechanisms including turgor pressure and translocation of various organic/inorganic compounds. N, P and K are vital nutrients required by all plants for balanced growth at different stages of development. The availability and movement of these minerals is primarily influenced by frequency and quantity of irrigation water (Treseder, 2001; Aujla *et al*., 2005; Buttar *et al*., 2006; Sarwar *et al*., 2008).

Different combinations of FYM (farmyard manure) with organic/inorganic nutrients had a significant impact on biological yield and growth parameters (like plant height, plant diameter, shoot length and root length etc). The application of microbial inoculants showed a sponsoring effect on different parameters and biomass of the plants. It has been established that organic fertilizers not only provide nitrogen, but also produce a variety of growth-promoting substances that facilitate plant growth (Zhao *et al*., 2016). Decline in application of fertilizer and amount of irrigation applied results in decreased tree growth, whereas excessive application can result in mortality (Ajayi, 2007). Determining the opposite levels of water and fertilizer application is important for proper plant growth (Malingreau *et al*., 2012).

Researches revealed that *V. nilotica* and *B.ceiba* responded significantly against different levels of irrigation with various combinations of organic and organic fertilizers. For instance, the maximum height and diameter were recorded at maximum irrigation and fertilizers levels. Availability of nutrients in soil eventually determines their uptake by plants (Jedidi *et al*., 2004). Similarly, in current study *V. nilotica* and *B. ceiba* showed minimum shoot weight in control conditions whereas maximum shoot fresh weight was recorded at maximum amount of water and fertilizer application applied. These results are confirmed by the conclusions of Beheshti and Fard, (2010) who suggested that increased levels of water and different fertilizer can promote plant growth regarding plant biomass, shoot/branch weight, shoot length, thickness and overall performance etc.

Percival *et al*., (2003), and Alsafar and Al-Hassan, (2009) reported that *V. nilotica* and *B. ceiba* produced minimum shoot and root dry weight in control conditions. He further suggested that water stress and lack of fertilizer applications also significantly impacted shoot dry weight etc. It was reported that variation in dry weight is closely linked with availability of nitrogen and phosphorus that may direct change of use of water (Wilson *et al*., 2005; Bucci *et al*., 2006; Saha *et al*., 2008; Brady, 2015). Similarly, in current trial maximum root fresh/dry weight of *V. nilotica* and *B. ceiba* were exhibited at highest level of irrigation and fertilizer and vice versa. These conclusions are fairly in line with the outcome of Ajayi, (2007 who showed that augmented fertility can influence the structural design and root biomass production in plants. Likewise, findings were observed in the current study, in which minimum photosynthetic rate was recorded in *V. nilotica* and *B.*

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ceiba species in control conditions. These outcomes agree with the findings of Pandey *et al*. (2005) who reported that poor leaf growth can lead to terrible photosynthetic rate in plants.

CONCLUSION

The results concluded that the addition of different organic and inorganic fertilizers could enhance the growth of selected tree species *V. nilotica* and *B. ceiba*. The maximum growth and biomass was found at higher fertilizer levels. Different irrigation levels also behaved significantly and showed higher growth response at maximum irrigation level.

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