

## Research Article

# Response of Short Duration Tropical Legumes and Maize to Water Stress: A Glasshouse Study

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The study was conducted as a pot experiment in the tropical glasshouse to evaluate the response of grain legumes (*Phaseolus vulgaris*, *Vigna unguiculata*, and *Lablab purpureus*) in comparison to maize (*Zea mays*) and estimate their potential and performance. Two experiments were established using completely randomized design. Physiological measurements (stomatal conductance, photosynthetic activities, and transpiration rates) were measured using LCpro instrument. Scholander bomb was used for the measurement of plant cell water potential. Significant difference was observed in different plant species with increase of different water regimes. Among the legumes, *L. purpureus* showed better response in water stressed conditions. At the beginning, in dry watered treatment the photosynthetic rate was below  $0 \mu\text{mol m}^{-2} \text{s}^{-1}$  and in fully watered condition it was  $48 \mu\text{mol m}^{-2} \text{s}^{-1}$ . In dry treatment, total dry weight was 10 g/pot and in fully watered condition it was near to 20 g/pot in *P. vulgaris*. The study concludes that water stress condition should be taken into consideration for such type of crop cultivation in arid and semiarid regions.

## 1. Introduction

Water is the most common limiting factor to primary productivity in arid and semiarid areas [1]. Areas with higher precipitation in a region have more above-ground primary productivity [2, 3]. Water-use efficiency is often equated with drought resistance and the improvement of crop yield under stress conditions [4]. Water has an influence on grain yield and yield contributing parameters. Canopy development is sensitive to water deficit [5]. Water stress is one of the most important factors for legumes production. It affects not only the production of the grains but also the whole process of growth of all organs of the plants and metabolism [6]. Plant growth and development are affected by water stress affecting physiological and biochemical processes, for example, ion uptake, photosynthesis, respiration and translocation [7–11]. Environmental stresses such as drought, salinity, heat, and cold represent a significant constraint to meet the world food demand, for example, Islamic Republic of Iran, especially

under low precipitation (often <250 mm per annum). Furthermore, the uneven temporal and spatial distributions have diode agronomists to pick the foremost effective irrigation strategies or drought tolerant cultivars [12].

Grain legumes are a major source of protein in arid and semiarid regions of the world and play a key role in the economies of arid and semiarid regions [13]. Multipurpose (dual purpose) legumes provide fodder, forage, green manure, seeds, and leaves that are used in human food [14]. Cowpea (*Vigna unguiculata* L.) and lablab (*Lablab purpureus* L.) widely cultivated in the tropics have multipurpose uses [15, 16]. *L. purpureus* has been comparatively neglected in analysis and development and consequently our information of its genetic diversity is proscribed [16, 17].

Legumes fix atmospheric nitrogen and are important to restore soil fertility. Legumes also play important role in breakdown of disease cycles, improve physical structure of soil, encourage microorganisms, and release available phosphorus to the soil [18].

Morphological and physiological understanding of legumes could be useful for selecting varieties to obtain better yield under drought conditions [19, 20]. The response of plants to water stress varies considerably and depends upon the intensity and duration of stress as well as of genotype and growth stages of the plant [10, 21]. Understanding plant response to drought is important and essential to develop drought tolerant crops [22, 23].

### 1.1. Grain Legumes

**1.1.1. Common Bean (*Phaseolus vulgaris* L.).** *P. vulgaris* one of the most important legume species in the developing countries and three quarters of the world production (8.5 million tonnes) is cultivated annually [24]. A major constraint to bean production in many developing countries is drought, which affects 73% of the area planted to beans in Latin America [25]. More than 300 million people get protein, carbohydrates, and minerals from grain legumes such as *V. unguiculata* in these regions. *P. vulgaris* is the second important source of calories after *Z. mays* in many areas of the Sub-Saharan Africa [26]. *P. vulgaris* is primarily a food in sub-Saharan Africa. Furthermore, millions of small-scale farmers in Latin America and Africa rely on the production and sale of bean as an important source of household income.

**1.1.2. Cowpea (*Vigna unguiculata* L.).** *V. unguiculata* is also one of the most important grain legumes in the diet of humans living in the tropics and subtropics. *V. unguiculata* is also a major crop in West and Central Africa for livelihood of millions of people. They use it as food and fodder and also for cash income. *V. unguiculata* grains contain protein which is not expensive and both rural people and urban consumers use it as a major protein source. *V. unguiculata* grain contains about 25% protein and 64% carbohydrate [27]. *V. unguiculata* is a legume crop which is grown in hot-dry tropics and subtropics. It plays a substantial role by serving as grain and vegetables crop for the rural people in the east, west, south, and central part of Africa [28]. It is truly a dual purpose grain legume crop, providing food for man and feed for livestock and serving as a valuable and dependable revenue-generating commodity for small holder farmers and grain traders [29, 30]. *V. unguiculata* is also a valuable component of farming systems where soil fertility is limiting because *V. unguiculata* has a high rate of nitrogen fixation [31] and forms effective symbiosis with mycorrhizae [32] and has the ability to better tolerate a wide range of soil pH compared to other grain legumes [33]. *V. unguiculata* is utilized in crop rotation and it improves soil fertility for yield of the cereal grains [34–36]. In the developing countries where soil infertility is high, rainfall is limiting, and most of *V. unguiculata* is grown without the use of fertilizers and plant protection measures (i.e., pesticides or herbicides), and a wide variety of biotic and abiotic constraints also limit growth and severely limit yield [37, 38].

**1.1.3. Lablab (*Lablab purpureus* L.).** *L. purpureus* is fast growing multipurpose legume which is grown in tropical region.

Grain and forage types exist. It is suitable for ley and forage in Australia. *L. purpureus* originated from Africa but now it is cultivated in many tropical countries. It is grown as a grain legume crop in India and Africa. It is also adapted to grow in a wide range of rainfall and temperatures [39]. *L. purpureus* yields 4000 kg dry matter (DM)/ha of above-ground biomass in Australia under dry-land condition [40, 41]. Furthermore *L. purpureus* improves nitrogen (N) fertility of the soil [42, 43]. *L. purpureus* germination generally occurs within 5 days after planting. The growth period ranges between 75 and 300 days. Fruiting of some cultivars can be within 60–65 days of sowing and continues for 90–100 days. *L. purpureus* is adapted to drought condition [44] and known to be even more drought tolerant than *P. vulgaris* or *V. unguiculata* [45].

**1.1.4. Maize (*Zea mays* L.).** *Z. mays* is one of the important cereal crop species after wheat and rice. It grows throughout a wide range of climates [46]. *Z. mays* shows susceptibility to drought in every stage but these three stages are more crucial for drought stress, that is, early growth stage, flowering stage, and mid-to-late grain filling stage [47]. Although *Z. mays* makes efficient use of water, it is considered more susceptible to water stress than other crops because of its unusual floral structure with separate male and female floral organs and the near-synchronous development of florets on a single ear borne on each. Low wet dry spore grains reduce the silk receptiveness and spore viability. *Z. mays* has completely different responses to water deficit consistent with development stages [48]. Drought stress is particularly damaging to grain yield if it occurs early in the growing season at flowering and during mid-to-late grain filling [49]. During the seedling stage, water stress damages secondary root growth and development. Stem growth and development after floral initiation show rapidly in adequate amount of water. Plants will be shorter and will decrease individual and cumulative area in water stress condition [50]. Ten to fourteen days before and after flowering of the *Z. mays* is the critical time for water stress. During the flowering stage grain yield reduces two to three times than any other stages of the growing period of *Z. mays* [51]. *Z. mays* grain yield is correlated with kernel number per plant during the water stress at flowering and grain filling stages [52], highlighting the importance of adequate water supplies during flowering.

The study was conducted to evaluate the drought tolerance of grain legumes compared to *Z. mays* by measuring agronomic (biomass production, leaf area, and yield) and physiological parameters (stomata conductance and photosynthetic activity) and to identify phenotypic variability of three commonly grown grain legume species in semi-arid Africa compared with the common staple cereal crop *Z. mays* in Africa.

## 2. Materials and Methods

**2.1. Materials.** In experiments, common bean (*P. vulgaris*, KATX 56), cowpea (*V. unguiculata*, M 66), lablab (*L. purpureus*, Q 6880B), and maize (*Z. mays*, Ronaldinio KWS)



FIGURE 1: Seed of 4 species used in the experiment.

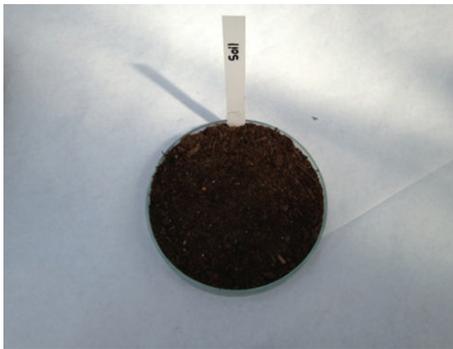


FIGURE 2: Soil used for the pot experiment.

were used in a glasshouse pot experiment (Figure 1). Figure 2 shows the soil used for the pot experiment.

**2.2. Methods.** Two glasshouse pot experiments were conducted as in the tropical glasshouse at Department of Crop Production Systems in the Tropics, Georg August University Göttingen, Göttingen, Germany. Experiment 1 was set using CRD with 3 different water regimes as treatments and replicated four times. Four species (*P. vulgaris*, *V. unguiculata*, *L. purpureus*, and *Z. mays*) were used in this experiment. Treatments were applied as (1) fully watered (watering three times in a week), (2) moderately watered (watering two times in a week), and (3) partially watered (watering one time in a week). Experiment 2 was set using CRD with 5 different water regimes as treatments and replicated three times. Three species (*P. vulgaris*, *V. unguiculata*, and *L. purpureus*) were used in this experiment. At first every pot was watered depending on weather condition. Treatments were applied as (1) fully watered (watering three times in a week), (2) moderately watered (watering two times in a week), (3) partially watered (watering one time in a week), (4) nearly dry (watering one time in every two weeks), and (5) dry (watering one time in every three weeks). Pot with a diameter of 23.5 cm and a depth of 19 cm with an internal capacity of approximately 8 lt. was used for both experiments. Pots were filled with substrate, clay, compost, and Schoninger sand (Figure 3). Soil pH (6.5) and bulk density ( $0.7 \text{ gm/cm}^3$ ) were measured before pot filling. Seeds were soaked in

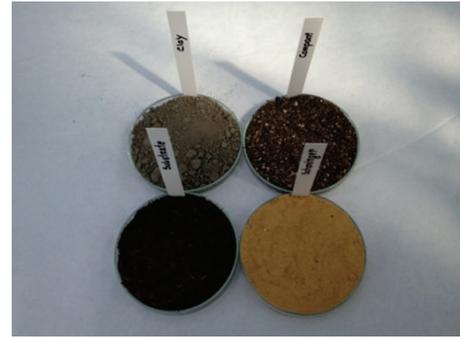


FIGURE 3: Components used for soil mix.

distilled water for 24 hours and planted into pots directly. Three seeds were planted in each pot at a depth of 4.0 cm approximately. The pots were watered to field capacity by repeated watering. After germination pots were thinned to one plant per pot, pots were subsequently watered according to the above described treatments from 3 weeks after planting. Soil volumetric water content was measured by soil moisture meter (TDR) in a week once before watering and after watering. Data were taken from 12 cm deep of the soil. Physiological measurements (stomatal conductance, photosynthetic activities, and transpiration) were taken using LCpro-SD, ADC, BioScientific Ltd. Data were analysed using Statistica software version 10 and MS excel 2007. Treatment effects and interactions were considered statistically significant at  $\leq 0.05$  level of probability.

### 3. Results

**3.1. Cell Water Potential in Experiment 1.** The water potential was significantly different for the different plant species tested in the experiment during the vegetative stage. It can be assumed that higher water potential of the cells had higher water stress. For the partially watered treatment water potential was the highest for all tested plant species. But the intensity of the responsiveness differed among plant species. *Z. mays* seemed to be stressed the most (high plant cell water potential for the partially watered treatment) followed by *P. vulgaris*, whereas the cell water potential remained stable for the legumes *V. unguiculata* and *L. purpureus*. Plant cell water potential of *L. purpureus* and *V. unguiculata* was 5 and 6 bar in partially watered condition. It is a good sign for drought tolerance. On the other hand, water potential of *P. vulgaris* and *Z. mays* was 11 and 17 bar, respectively, in fully watered condition (Figure 4).

**3.2. Dry Weight of *P. vulgaris*, *V. unguiculata*, *L. purpureus*, and *Z. mays* in Experiment 1.** Higher water regimes showed higher dry weight in all legumes and they also showed significant difference between different water levels. But interaction between different plants and water regimes did not show significant difference. Total dry weight was about 43 g/pot in fully watered condition in common bean, whereas *V. unguiculata* and *L. purpureus* had 40 g/pot dry weight.

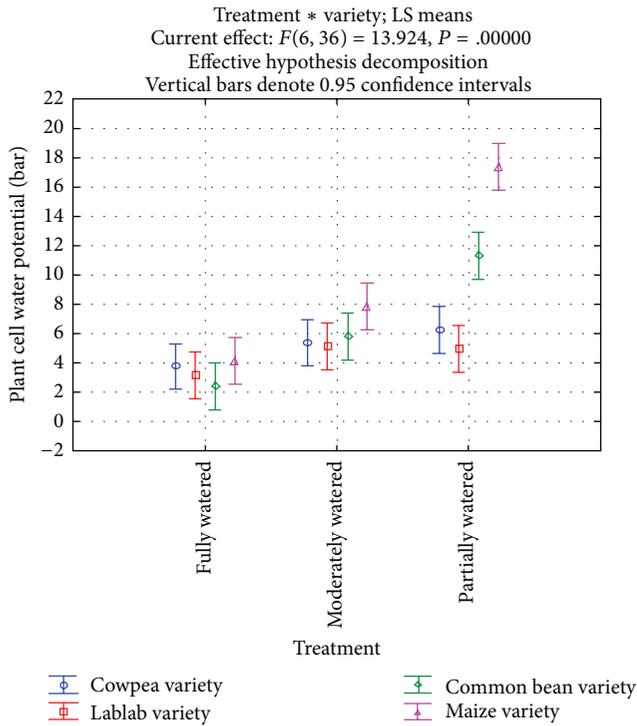


FIGURE 4: Plant cell water potential of *P. vulgaris*, *V. unguiculata*, *L. purpureus*, and *Z. mays* under different treatments in experiment 1.

Besides, partially watered condition *V. unguiculata* showed the highest value than other legumes, but *L. purpureus* showed the highest value in moderately watered treatment. This means that *V. unguiculata* and *L. purpureus* had low water use efficiency than *P. vulgaris* and partially watered condition *V. unguiculata* showed better yield than other legumes. On the other hand, *L. purpureus* had about 35 g/pot dry weight in partially watered treatment. Water stress affects total dry in *P. vulgaris*. In partially watered treatment, total dry weight was 20 g/pot in *P. vulgaris*. *P. vulgaris* showed above 40 g/pot total dry weight fully watered condition (Figure 5).

3.3. Stem-Leaf Ratio of *V. unguiculata*, *L. purpureus*, *P. vulgaris*, and *Z. mays* in Experiment 1. Different water regimes showed significant difference and different species also showed significant difference but interaction between variety and water regimes did not show significant difference. *L. purpureus* showed lowest stem and leaf ratio in fully watered condition in comparison to the moderately and partially watered treatments. This means that *L. purpureus* has low water use efficiency. On the other hand, non-legume crop, *Z. mays*, has more water use efficiency and water level was increased and hence, stem and leaf ratio showed higher value. In fully watered conditions, *Z. mays* had stem and leaf ratio was about 4.6 (Figure 6) than other watering treatments.

3.4. Soil Moisture Content in Different Treatments of Four Species. Differences between crops in the same watering

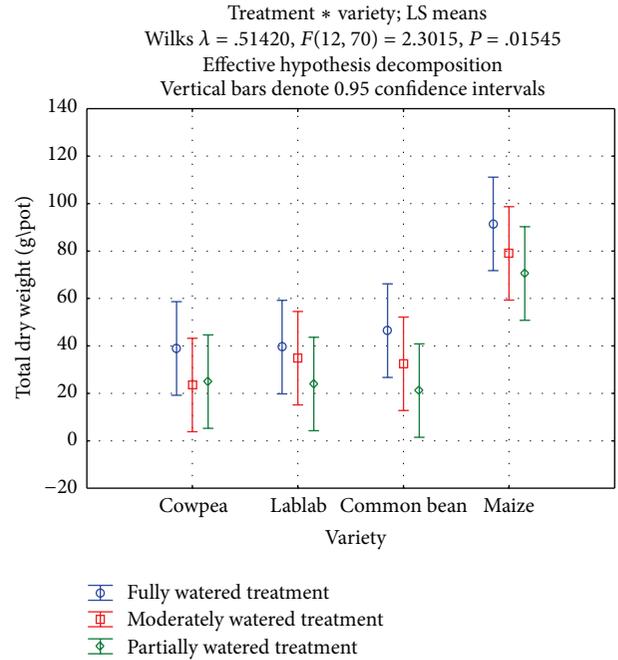


FIGURE 5: Total dry weight in different plants according to different watering treatments.

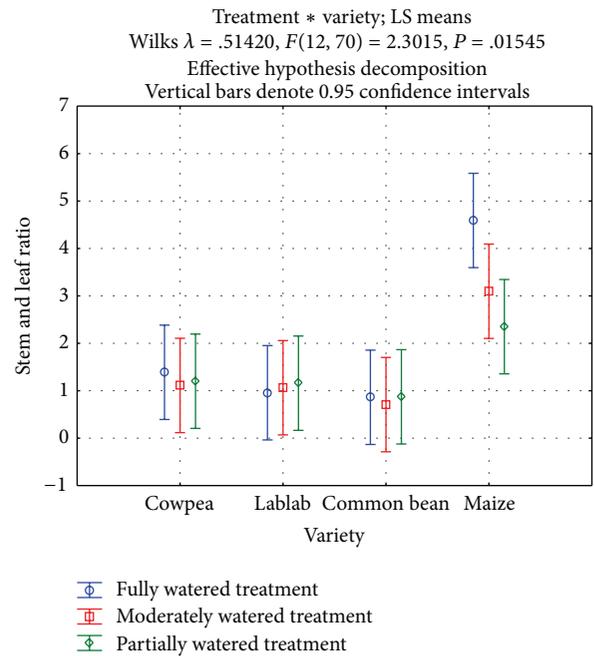


FIGURE 6: Stem-leaf ratio in different legumes according to different watering treatments.

regime were often small except fully watered condition. In case of dry, nearly dry, and moderately watered conditions, water consumption of *L. purpureus*, *V. unguiculata*, and *P. vulgaris* was much more similar, but in fully watered conditions, *P. vulgaris* uptake more water than other crops. *V. unguiculata* and *L. purpureus* consumed less water in fully watered condition (Figure 7).

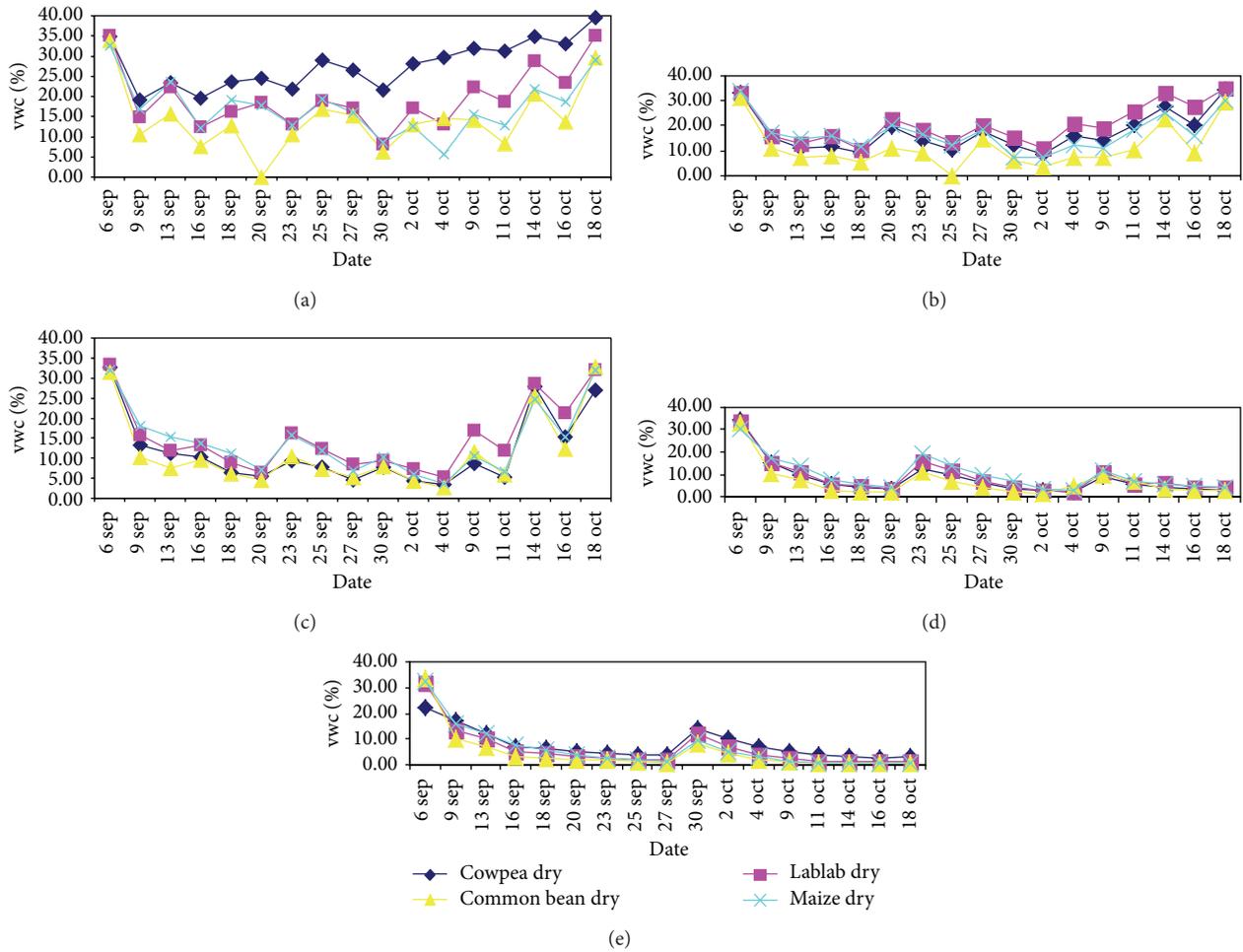


FIGURE 7: Soil moisture content of different water level: (a) fully watered (b) partially watered (c) moderately watered, (d) near to dry, and (e) dry.

3.5. *Photosynthesis of V. unguiculata, L. purpureus, and P. vulgaris in Experiment 2.* Photosynthesis showed significant difference in variety and treatment interaction between before and after watering. Before watering, *V. unguiculata* showed the highest photosynthesis rate compared to the other plant species tested in dry condition. *L. purpureus* showed gradually increase of photosynthesis before and after watering (Figures 8 and 9). Photosynthesis was little bit increased in *P. vulgaris* and decreased in *L. purpureus* and *V. unguiculata* through watering. This also indicated that *L. purpureus* had lower water use efficiency than *P. vulgaris*.

3.6. *Stomatal Conductance of V. unguiculata, L. purpureus, and P. vulgaris in Experiment 2.* Stomatal conductance showed significant difference in different water regimes in legumes. In *P. vulgaris*, stomatal conductance was increased when the water level increased. *P. vulgaris* showed more water use efficiency and stomatal conductance was gradually increased with the increase of water regimes. *L. purpureus* and *V. unguiculata* did not show too much variation; only *L. purpureus* in dry treatment suddenly showed very high stomatal conductance. *L. purpureus* and *V. unguiculata* showed less

water use efficiency than *P. vulgaris*. After watering, it showed that *P. vulgaris* showed higher stomatal conductance in nearly dry, moderately watered, and partially watered treatments. In *L. purpureus*, stomatal conductance was increased in case of nearly dry and moderately watered conditions but decreased little bit in fully watered and partially watered conditions. After watering, *V. unguiculata* showed water use efficiency in nearly dry and moderately watered conditions, but there was no change in fully watered and partially watered conditions (Figures 10 and 11).

3.7. *Transpiration of V. unguiculata, L. purpureus, and P. vulgaris in Experiment 2.* Water regimes showed significant difference in transpiration before and after water use in different plants. In *P. vulgaris*, transpiration increased with the increase of water level except in dry treatment. After watering, evaporation increased slightly with the increase of water level in nearly dry and moderately watered conditions in *L. purpureus*, but transpiration was increased in partially and fully watered condition. In *V. unguiculata*, transpiration was increased in nearly dry and moderately watered

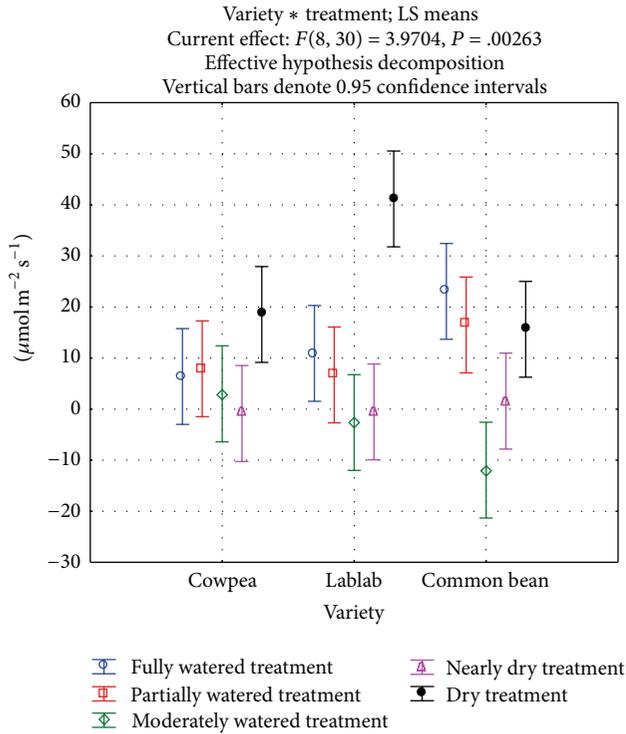


FIGURE 8: Photosynthesis rate on 55 DAP.

conditions but decreased in partially and fully watered conditions on 55 DAP (Figures 12 and 13).

3.8. *Photosynthesis of V. unguiculata, L. purpureus, and P. vulgaris on 55 DAP and 58 DAP in Experiment 2.* Photosynthesis rate showed significant differences between different varieties and watering treatments on 55 DAP and 58 DAP. On 58 DAP, all varieties showed the highest photosynthesis rate in fully watered condition. On 55 DAP, *P. vulgaris* showed that increase of water level gradually increased photosynthetic rate. At the beginning, in dry watered treatment the photosynthetic rate was below  $0 \mu\text{mol m}^{-2} \text{s}^{-1}$  and finally in fully watered condition it was  $48 \mu\text{mol m}^{-2} \text{s}^{-1}$ . Water level was increased followed by the increase of photosynthetic rate in fully watered condition. *V. unguiculata* and *L. purpureus* showed response to water level very well, but water use efficiency was lower in case of *V. unguiculata* and *L. purpureus* than compared to *P. vulgaris* (Figures 14 and 15).

3.9. *Stomatal Conductance of V. unguiculata, L. purpureus, and P. vulgaris on 55 DAP and 58 DAP in Experiment 2.* On 55 DAP, stomatal conductance showed significant difference in different legumes at different water regimes, but on 58 DAP stomatal conductance did not show significant difference. Stomatal conductance was gradually increased in *V. unguiculata* except for dry water treatments on 55 DAP (Figures 16 and 17).

3.10. *Transpiration of V. unguiculata, L. purpureus, and P. vulgaris on 55 DAP and 58 DAP in Experiment 2.* Transpiration

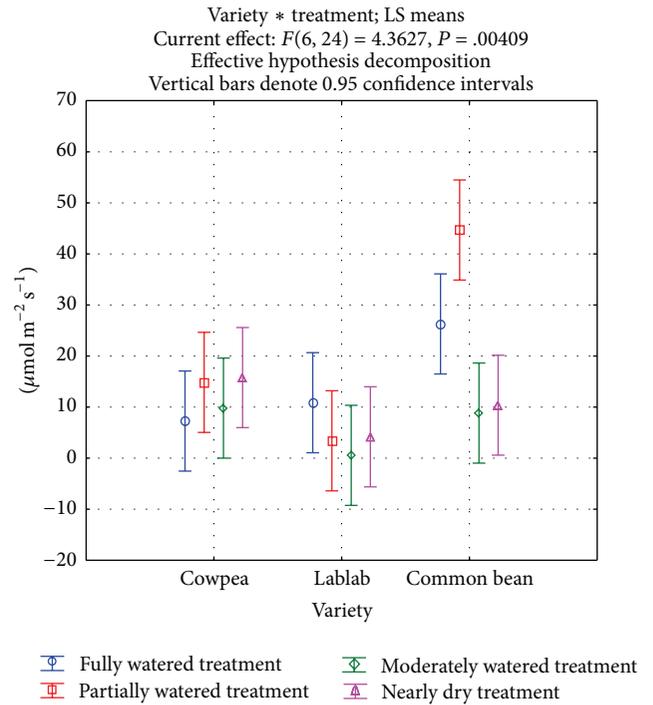


FIGURE 9: Photosynthesis rate on 58 DAP.

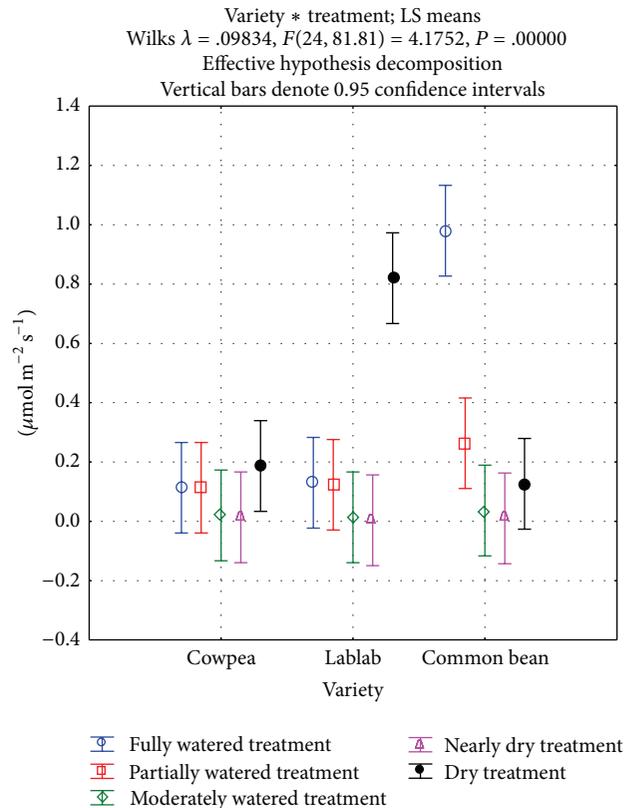


FIGURE 10: Stomatal conductance on 55 DAP.

showed significant differences with different water treatments on 55 DAP and 58 DAP in different plants. *P. vulgaris* showed

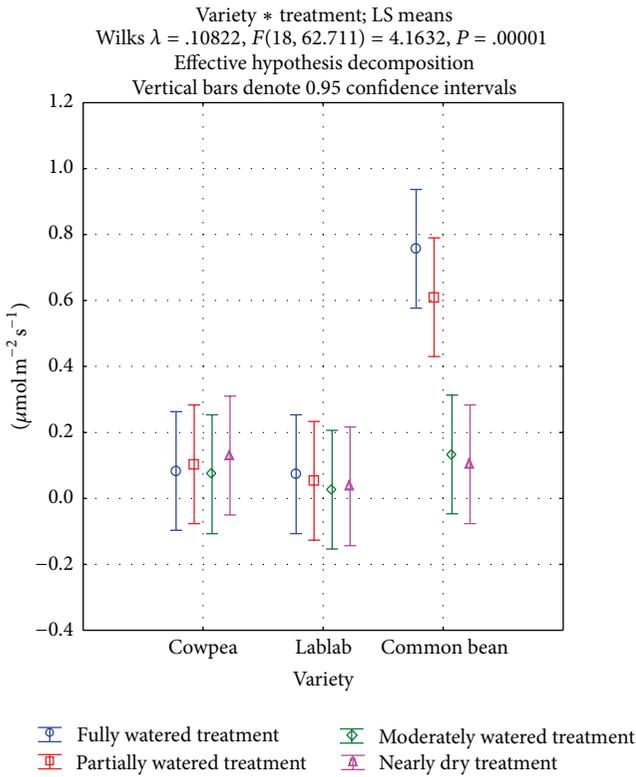


FIGURE 11: Stomatal conductance on 58 DAP.

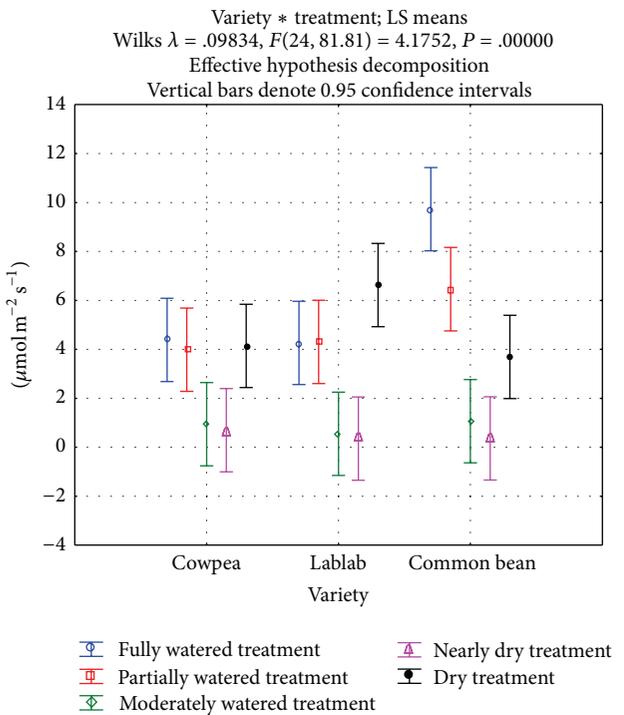


FIGURE 12: Transpiration on 55 DAP.

the gradual increases of transpiration with increasing water levels on 55 DAP. *L. purpureus* and *V. unguiculata* showed

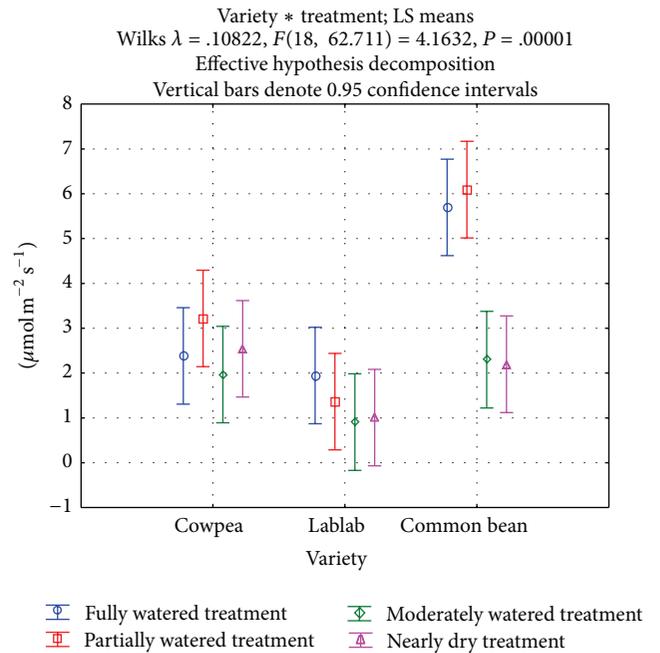


FIGURE 13: Transpiration on 58 DAP.

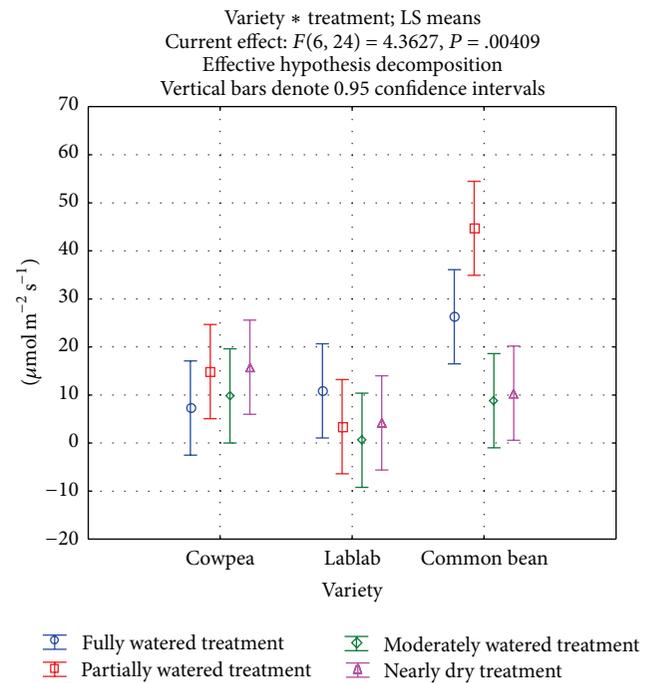


FIGURE 14: Photosynthesis on 55 DAP.

higher transpiration in fully watered condition on 55 DAP, but other treatments showed very little variation. *P. vulgaris* had more water use efficiency on 55 DAP. *P. vulgaris* also showed gradual increase of evaporation rate in different water regimes on 58 DAP. On 58 DAP, transpiration rate was increased after watering in *P. vulgaris* (Figures 18 and 19).

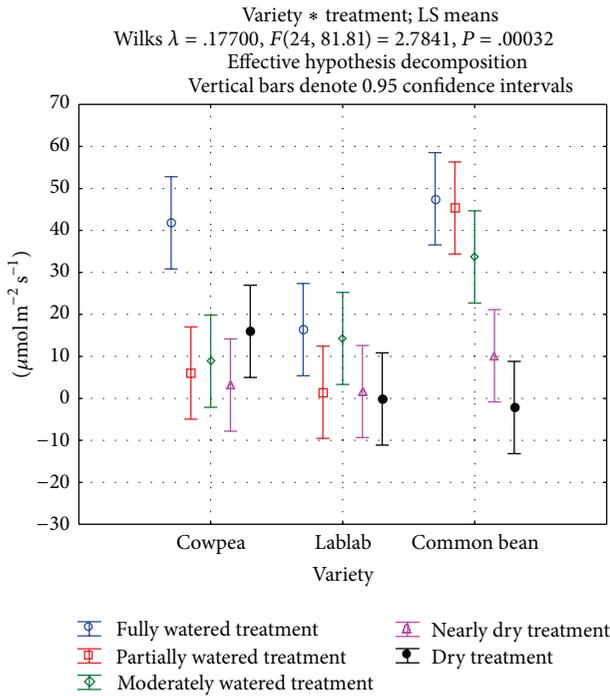


FIGURE 15: Photosynthesis rate on 58 DAP.

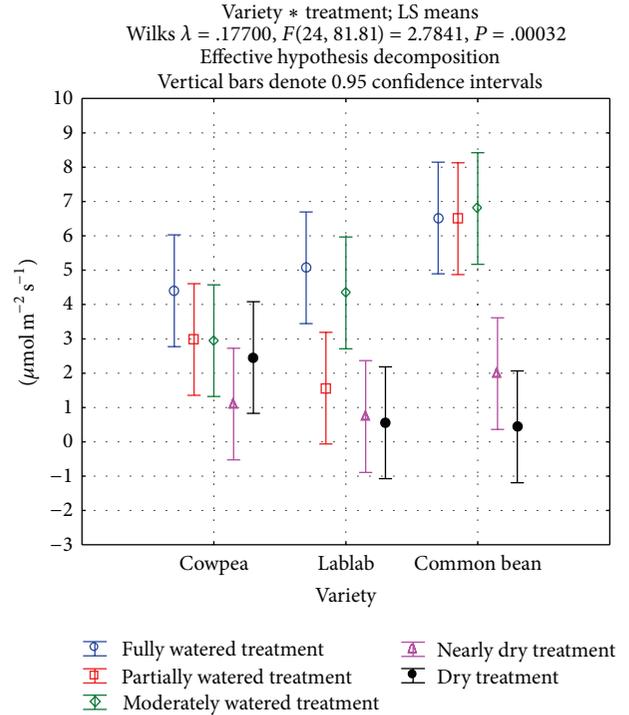


FIGURE 16: Stomatal conductance on 55 DAP.

3.11. *Stem-Leaf Ratio of V. unguiculata, L. purpureus, and P. vulgaris in Experiment 2.* Different water regimes and species followed significant difference and also the interaction between species and different water level showed significant difference. *P. vulgaris* showed the lowest stem leaf ratio in comparison to the other legume species in different water regimes. *V. unguiculata* had the highest stem leaf ratio compared to the other crops in fully watered condition. There was a clear effect of the watering treatment on the leaf stem ratio. The leaf stem ratio was increased for all plant species with increased water availability. Different plant species had different water use efficiency. But it was also clear that availability of water was responsible for increased stem and leaf ratio (Figure 20).

3.12. *Total Dry Weight of V. unguiculata, L. purpureus, and P. vulgaris in Experiment 2.* The effect of different water treatments on plant biomass production and dry weight was different among the three different legume species. For *P. vulgaris*, dry weight was decreased with the increased water stress. In dry treatment, total dry weight was 10 g/pot and in fully watered condition it was near to 20 g/pot in *P. vulgaris*. Total dry weight was increased double in *P. vulgaris* when water level was higher. For *L. purpureus* the effect of different water treatments on dry weight was not pronounced and remained almost constant. Surprisingly, *V. unguiculata* showed the highest dry weight in the moderately watered plants. Moderately watered condition showed the highest dry weight compared to the other treatments (Figure 21).

## 4. Discussions

*L. purpureus* showed gradually increased photosynthetic rate with response to different water level. In *P. vulgaris*, stomatal conductance was increased when the water level was increased and in fully watered condition it showed almost  $1 \mu\text{mol m}^{-2} \text{s}^{-1}$ . *L. purpureus* and *V. unguiculata* did not show too much variation. Stomatal conductance was highest in *P. vulgaris*. *L. purpureus*, *V. unguiculata*, and *P. vulgaris* showed  $0.0 \mu\text{mol m}^{-2} \text{s}^{-1}$  stomatal conductance in nearly dry watering treatment, but in fully watered treatment stomatal conductance uplifted to  $0.1 \mu\text{mol m}^{-2} \text{s}^{-1}$  in *V. unguiculata* and *L. purpureus* each, and *P. vulgaris* gave value near to  $1.0 \mu\text{mol m}^{-2} \text{s}^{-1}$ . The finding is also in agreement with Vogel et al. [53]. Among the legumes, *L. purpureus* showed lower photosynthetic rate than the other legumes. *P. vulgaris* had more water use efficiency than other legumes and stomatal conductance was gradually increased in regard to higher water regimes. *L. purpureus* and *V. unguiculata* did not show too much variation. *L. purpureus* and *V. unguiculata* followed less water use efficiency. In *L. purpureus*, stomatal conductance was increased in case of nearly dry and moderately watered conditions but decreased slightly in fully and partially watered conditions. The stomatal conductance was above  $0.7 \mu\text{mol m}^{-2} \text{s}^{-1}$  in fully watered treatment and  $0.1 \mu\text{mol m}^{-2} \text{s}^{-1}$  in partially watered treatment. On the other hand, *V. unguiculata* and *P. vulgaris* did not show too much change in fully watered treatment. Photosynthetic rate in *P. vulgaris* was increased with the increase of water level on 55 DAP. In dry watered treatment the photosynthetic rate was below  $0 \mu\text{mol m}^{-2} \text{s}^{-1}$ , but in fully watered condition

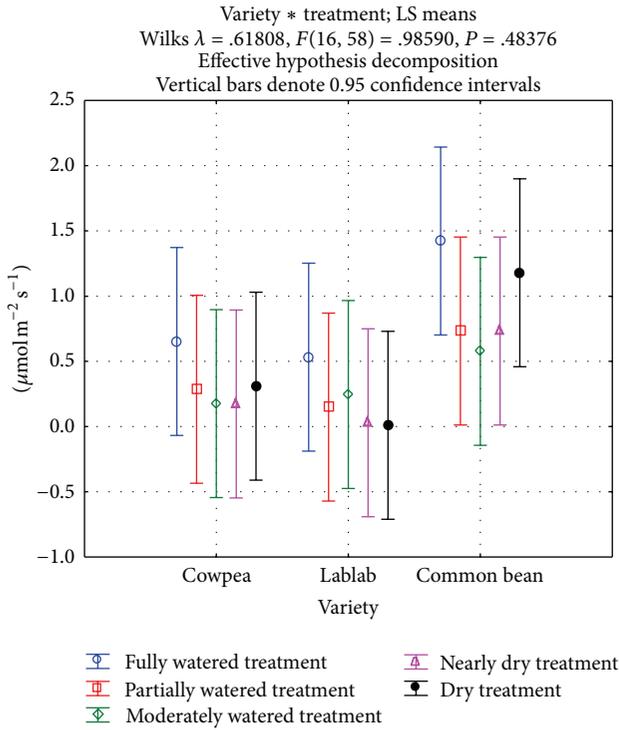


FIGURE 17: Stomatal conductance on 58 DAP.

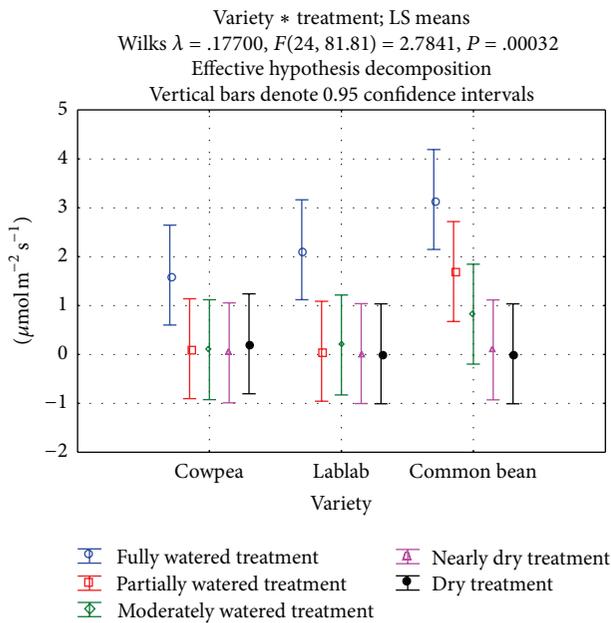


FIGURE 18: Transpiration on 55 DAP.

it was  $48 \mu\text{mol m}^{-2} \text{s}^{-1}$ . Moreover, *V. unguiculata* and *L. purpureus* also showed positive response to water level but lower water use efficiency than *P. vulgaris*. *P. vulgaris* showed the gradual increases of transpiration with increasing water levels on 55 DAP. *L. purpureus* and *V. unguiculata* showed higher transpiration in fully watered conditions on 55 DAP. After watering the plants, *P. vulgaris* also showed gradually

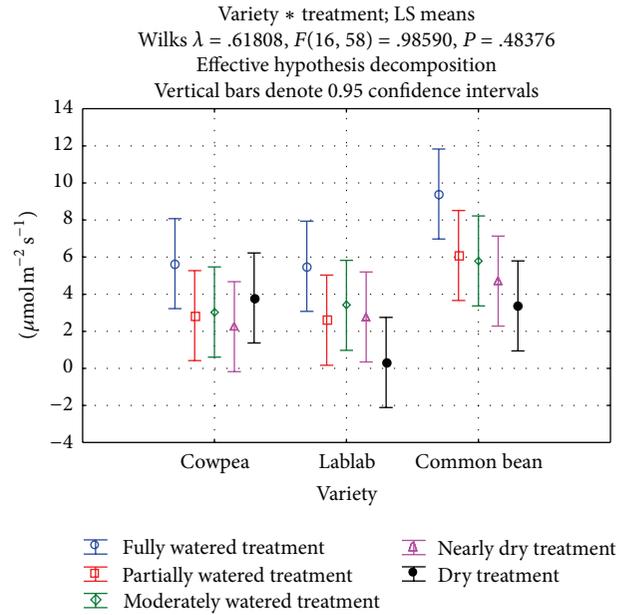


FIGURE 19: Transpiration on 58 DAP.

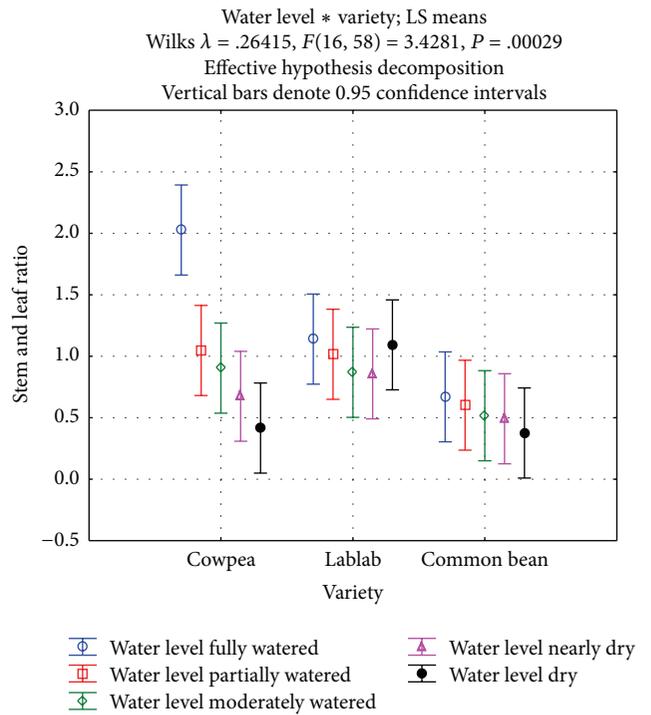


FIGURE 20: Stem-leaf ratio in different plants according to different watering treatments.

increases of transpiration rate in different water regimes on 58 DAP. It is proved that after watering transpiration rate was raised in all legumes, *P. vulgaris* showed clear gradual increase of transpiration than the other legumes. Higher water regimes showed higher dry weight in all legumes and they also showed significant difference between different water levels. Total dry weight in common bean was more (42 g/pot) in fully watered

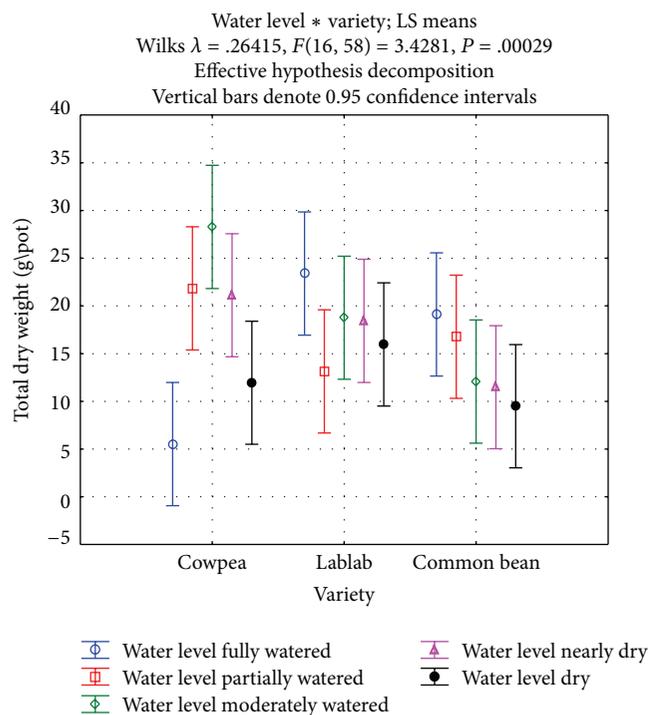


FIGURE 21: Total dry weight in different plants according to different watering treatments.

condition. *V. unguiculata* and *L. purpureus* had 40 g/pot dry weight. Besides, in partially watered condition, *V. unguiculata* showed the highest value compared to the other legumes. On the other hand, *L. purpureus* had about 35 g/pot dry weight. In partially watered treatment, total dry weight was 20 g/pot in *P. vulgaris*. Yield was reduced in *P. vulgaris* due to drought treatments. The water potential was significantly different for the different plant species tested in the experiment during the vegetative stage. It can be assumed that higher water potential of the cells belongs to higher water stress. For the partially water treatment water potential was highest for all tested plant species. But the intensity of the responsiveness differed among plant species. *Z. mays* needed adequate amount of water for its growth and development. Different legumes also showed different responses to water stress. *Z. mays* seemed to be stressed the most (high plant cell water potential for the partially water treatment) followed by beans, whereas the cell water potential remained stable for the legumes *V. unguiculata* and *L. purpureus*. Plant cell water potential of *L. purpureus* and *V. unguiculata* was 5 and 6 bar in partially watered condition. It is a good sign for drought tolerance.

## 5. Conclusion

Water is the most limiting factor for agricultural production in particular in the semiarid areas of the world. Legumes are of great importance for food security particularly in the developing world. Furthermore, they have the ability to improve soil fertility in resource constraint small holder farming systems. Drought is the most limiting environmental

factor for the productivity of crops in primarily rain-fed based farming systems of semiarid areas. Plant developed totally different methods to avoid or minimize drought stress. The study examines responsiveness of three legumes and *Z. mays* to water stress. Significant difference was observed in different plant species with increase of different water regimes. *L. purpureus* showed better response in water stress compared to the other species. *P. vulgaris* showed a negative effect on dry weight with increased water stress. Therefore, this study concludes that selection of crops in water stress condition is highly necessary to improve the crop production and ensure the agricultural and environmental sustainability.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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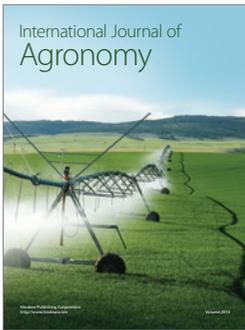
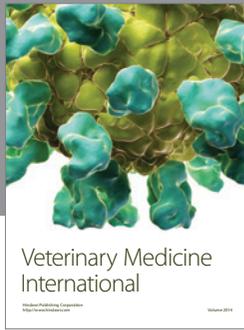
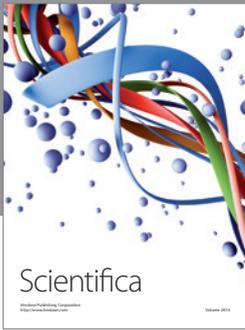
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