# Dry Matter Partitioning of Cowpea (Vigna Unguiculata (L.) Walp.) Under Water Deficit Conditions

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## Abstract

Water Stress caused reduction of seed yield in cowpea plants by decreasing total biomass and photosynthesis. The source leaf, pod and seed water potential of stressed cowpea were lower than water potential in non-stressed plants. No differences in water potential and turgor were observed between pod walls and seed of cowpea plants. Partitioning of the total above ground dry matter was similar for both stressed and nonstressed cowpea plants. Photosynthetic rates of single leaves from cowpea were greater for nonstressed than stressed plants. The duration of seed growth of cowpea was not different between stressed and nonstressed plants; however, rate of seed growth at the end of seed filling period was greater in nonstressed plants. Seed growth rate of both stressed and nonstressed cowpea plants declined at about the same time photosynthesis of the source leaf declined. Leaf area index was greatest in nonstressed cowpea.

## Introduction

Legume crops such as cowpea (Vigna unguiculata L. Walp.) are a major source of protein for human consumption in many developing countries. This is especially true for several African and Latin America countries where drought is a reoccurring phenomenon. Because of the drought conditions, cowpea seed yields are frequently reduced resulting in a decline of available food and protein for the people of these countries.

Yield and seed development requires the production of assimilates in leaves, translocation of these assimilates to the fruits, unloading of the assimilates from phloem of the seed coat into cells of cotyledons and synthesis of the various seed storage compounds. Yield component development of cowpea is directly linked to physiological processes such as photosynthesis, translocation, and partitioning. Yield losses resulting from water stress are generally associated with decreases in the activity of these physiological factors and dry matter production. The scarcity of information about how these physiological processes contribute to legume seed filling and yield under water stress conditions has prevented plant breeders from using these physiological traits to select for improved crop yields. In cereal crops, the relationship between yield and these physiological factors is reasonably understood as compared to legume crops. In wheat, drought appears to reduce the number of endosperm cells in the kernel and the number of starch granules in the endosperm cells.

The purpose of this study was to investigate the affect of water stress on the physiological and morphological factors associated with productivity of cowpea when grown under various water stress treatments.

## Material and Methods

Physiological factors measured were photosynthesis, water and osmotic potential, translocation, relative growth rates and dry matter partitioning. Morphological traits of pods and seeds were studied with scanning electron microscope. Field and glasshouse experiments were conducted under different light, temperature, and irrigation regimes.

Photosynthesis measurements were conducted with a IRGA Portable Photosynthesis System. One leaflet of trifoliolate leaf from three randomly selected plants was used for photosynthetic measurements. Trifoliolate leaf was not detached from the plant. Only trifoliolate leaflets adjacent to a growing pod, located between nodes 3 and 7 were selected for analysis. During photosynthetic measurements relative humidity inside the chamber was kept constant. The instrument was set to make two readings for each measurement, and each reading took about 60 to 90 sec. The chamber was kept in the shade between readings to avoid errors due to temperature increase at the chamber walls.

For water relations measurements, three 0.5 cm in diameter discs were taken from the lower portion of the youngest leaf blade, and from the following fruit structures, pod walls, cotyledons and seed coat found between nodes 5 to 9. Discs were immediately placed in single junction psychrometer chambers following their collection. Psychrometers were placed in a $25^0$C water bath. Water potentials were determined with a Wescor MJ-55 microvoltmeter 3 h after equilibration. For leaf osmotic potential determinations, the psychrometers were frozen in liquid nitrogen for 20 sec, allowed to thaw and equilibrated in the water bath ($25^0$C) for 1 h before measurements were made.

For electron microscope studies, seed coat strips and whole funiculi collected from stressed and nonstressed bean seeds and pods 10, 20, and 30, and 20 and 30 days after anthesis, respectively, were fixed in 1.5% (v/v) glutaraldehyde for 1.5 h and 6% (v/v) glutaraldehyde for 4 h at $25^0$C. After fixation, seed coat strips and funiculi were cooled to $4^0$C and washed four times over a 2 h period in 0.025 M phosphate buffer (pH 6.8) prior to 2 h post-fixation ($0^0$C) in 1% (v\v) osmium tetroxide 0.05 M phosphate buffer (pH 6.8). After post-fixation, tissue was washed twice in distilled water over a 1 h period and dehydrated in an acetone series (one 15 min change in 30, 50, 70, 85, 95% (v/v), and three 15 min change in 100%, (v/v). Tissues were then dried in a Polatron 1250 Critical Point Dry apparatus coated with 30 nm of gold in hummer sputter coated and examined under a I.S.I. DS-130 Scanning Electron Microscope.

## Results and Discussion

Table 1 shows that withholding water during the reproductive stages of cowpea development resulted in a significant decrease in yield. Yield loss caused by water stress appears to be due to the reduction in plant biomass. There appears to be decline in seed number per pod or pod number per plant. The loss of yield associated with water stress may be caused by lowering of the turgor pressure of the source leaf and yield components. Turgor pressure appears to regulate plant growth rather than water potential. The turgor pressure of cowpea in the dry and wet treatments were similar whereas the water potentials were different indicating that osmotic adjustment had occurred. The water potential of the dry treated cowpea was $-1.39 \pm 0.11$ as compared to $-0.82 \pm 0.03$ for the wet treated cowpea.

Water stress can decrease photosynthesis by either increasing stomatal resistance or affecting directly the biochemistry of the photosynthetic apparatus. The decrease of photosynthesis may reduce yield by decreasing the amount of assimilates required for plant growth and yield. Nonstressed cowpea plants had higher photosynthesis rates than stressed plants (Fig. 1).

The photosynthetic rates of stressed plants were zero on the 18 day after anthesis whereas photosynthetic rates of nonstressed plants were maintained a little longer reaching zero on 22 days after anthesis (Fig. 1). This difference in photosynthetic rate duration may be due to early leaf senescence in the stressed plants.

Partitioning of dry material remained fairly constant between treatments in field grown cowpea (Table 2); however, when plants were grown under greenhouse conditions, plants under water stress invested greater percentages of their dry matter in leaves than seeds. The amount of dry matter invested in stem and pod remained about the same.

The morphological studies of cowpea reproductive structures showed that there were no vascular connection between the pod walls and the seed. The funiculus of seed from stressed plants had greater numbers of scalariform vessels than nonstressed plants, suggesting that water movement occurred in these structures.

In summary, our research showed that (1) reduced plant dry weight and seed yield occurred because of reduced rated of assimilate production caused by water stress. (2) water stress reduced water potential in cowpea leaf and fruits, whereas, turgor pressure remained the same. (3) availability of assimilates for seed growth seems to be a more important factor than seed water potential in controlling seed development.

Table 1. The effect of two water treatments on yield and yield components of cowpea grown under field conditions.

| Yield and Yield Components | | |
|---|---|---|
| | Water Treatment | |
| Yield Components | WET | DRY |
| Dry weight per plant (g) | 50.1 A* | 29.4 B |
| Pod dry weight per plant (g/pl) | 17.4 A | 10.0 A |
| Pod number per plant (No) | 25.0 A | 24.0 A |
| Pod dry weight per area ($g/m^2$) | 44.9 A | 28.7 A |
| Seed number per pod (No) | 7.5 A | 6.6 A |
| Seed dry weight per plant (g/pl) | 86.2 A | 59.1 A |
| 100 seed wt. (g) | 24.0 A | 23.0 A |
| Seed dry weight per area ($g/m^2$) | 222.9 A | 176.6 B |
| YIELD (Kg/ha) | 2229.3 A | 1765.7 B |

*Means within the same row followed by the same letter are not significantly different at the 0.05 level.

Table 2. Dry weight partitioning in field and glasshouse grown cowpeas.

| PLANT STRUCTURE | FIELD | | GLASSHOUSE | |
|---|---|---|---|---|
| | TREATMENTS | | | |
| | WET | DRY | WET | DRY |
| | (%) | | | |
| Stem | 41.1 | 39.3 | 39.4 | 41.9 |
| Leaf | 24.5 | 24.6 | 28.5 | 33.7 |
| Pod | 6.1 | 5.7 | 0.6 | 1.0 |
| Seed | 24.5 | 26.2 | 31.5 | 23.8 |
| Flower | 3.9 | 4.1 | ---- | ---- |

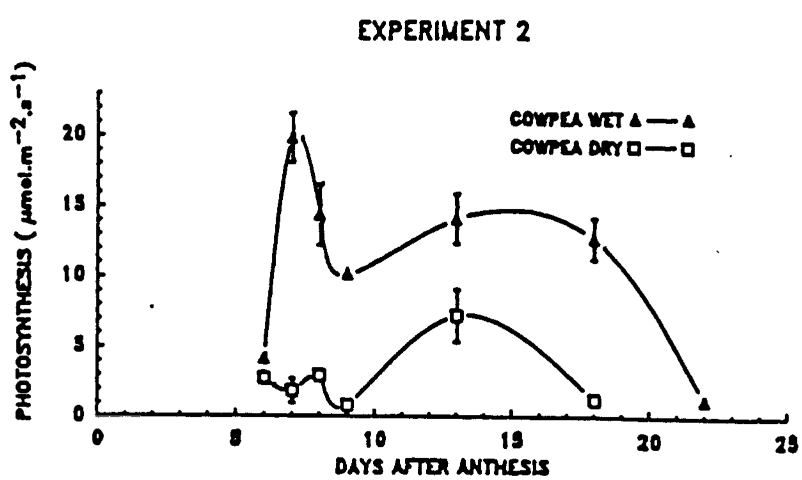


Fig. 1. Photosynthesis (PS), of stressed and nonstressed cowpea plants measured at 1200 h on different days after anthesis.