were counted and shoots of both species were oven-dried at 70 °C for 72 h and their dry weights were determined. Relative yield (RY) and relative yield total (RYT) of both species were calculated [2] from the following formula:

$$RY = \frac{\text{Yield of a species in mixture}}{\text{Yield of the same species in pure stand}}$$

Relative yield total (RYT) was calculated by adding the relative yields of the two species for the same treatment.

2.1.4. Statistics

Data on *A. retroflexus* and cowpea were summarized and species were subjected to ANOVA and regression analysis separately using MSTATC and SPSS software [11], respectively to test for significance ($P \leq 0.05$). The homogeneity and normality of error variance between treatments was tested before conducting any analysis and both were not significant. The main effects and interaction between treatments were calculated. Regression analysis has been suggested as an appropriate method to relate plant growth parameters to weed density [12]. Yield potential and intraspecific competition coefficient in monoculture were obtained by fitting the inverse of yield to seedling density in first experiment ($1/w = a + bN$ where w is yield per plant, a is the inverse of yield in absence of competition, b is intraspecific competition and N is number of plants per pot).

For growth analysis experiment, natural logarithm transformation was employed to linearilize the growth function curve: plant variables growth (Yt), ($\ln(Yt) = a + b{*}DAE$ where y is yield per plant at time t; a is initial yield, b is RGR and DAE is days after emergence) and regression analysis was conducted on transformed data.

Stepwise regression was employed to select variables to retain in the model when more than one independent variable was considered. The selection of the best multiple linear regression models was performed by starting with maximum independent variables and by eliminating terms with a forward stepwise analysis. Regression of independent variables on other independent variables resulting in a high R^2 indicates multicollinearity among the variables [13]. Variables with higher tolerance and lower multicollinearity significant partial regression coefficients ($P \leq 0.05$) were retained in the model.

RESULTS

3.1. Experiment 1. Effect of Water Stress on Growth of *A. retroflexus* and Cowpea Grown in Pure Stands at Various Densities

3.1.1. Effect on Cowpea

Water and density stress significantly reduced cowpea shoot dry weight and leaf area per plant (Fig. **1a** and **d**) and

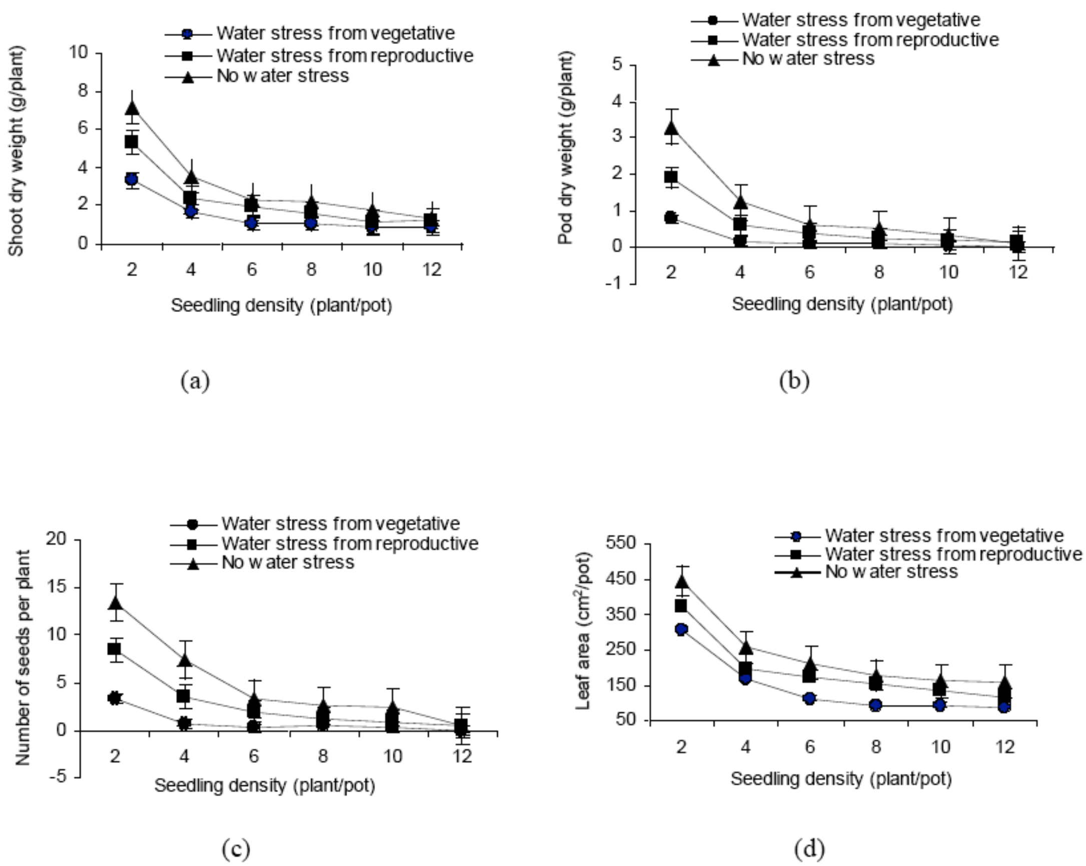

Fig. (1). Effect of different levels of water stress and seedlings density on **a**) shoot dry weight, **b**) pod dry weight, **c**) number of seeds and **d**) leaf area of cowpea. Error bars indicate SE of the means.

Table 1. Effect of Water Stress at Different Growth Stages on Model of Leaf Area Production and Shoot Dry Weight Per Plant of Cowpea and on Plant Height, Shoot Dry Weight and Inflorescence Dry Weight Per Plant of *A. retroflexus*

Method	Time of water stress	Function	R^2	P	N
Cowpea					
Growth	From vegetative to maturity	Ln (leaf area) = 2.77 + 0.12*WAE Ln (shoot dry weight) = 0.26+0.073* WAE	0.99 0.98	0.000 0.000	24 24
Growth	From flower to maturity	Ln (leaf area) = 3.26+0.11*WAE Ln (shoot dry weight) = 0.5+0.08* WAE	0.85 0.99	0.000 0.000	24 24
Growth	Optimum water during the season	Ln (leaf area) = 3.52+0.12*WAE Ln (shoot dry weight) = 0.86+0.088* WAE	0.99 0.97	0.000 0.000	24 24
A. retroflexus					
Growth Inverse	From vegetative to maturity	Ln (plant height) = 0.54 + 0.26*WAE Ln (shoot dry weight) = -0.29+0.24* WAE 1/Y(inflorescence dry weight) = 1.14*SD	0.95 0.95 0.95	0.000 0.000 0.0002	24 24 24
Growth Inverse	From flower to maturity	Ln (plant height) = 0.56 + 0.27*WAE Ln (shoot dry weight) = 0.0026+ 0.26* WAE 1/Y (inflorescence dry weight) = 0.92*SD	0.87 0.88 0.94	0.000 0.000 0.003	24 24 24
Growth Inverse	Optimum water during the season	Ln (plant height) = 0.59+ 0.29*WAE Ln (shoot dry weight) = -0.25 +0.27* WAE 1/Y(inflorescence dry weight) = 0.41*SD	0.88 0.88 0.97	0.000 0.000 0.0001	24 24 24

WAE = week after emergence.

Table 2. Effect of Seedling Density on Model of Leaf Area Production and Shoot Dry Weight Per Plant of Cowpea, and on Shoot Dry Weight and Plant Height of *A. retroflexus*

Method	Density (plants/pot)	Function	R^2	P	N	Function	R^2	P	N
		Cowpea				*A. retroflexus*			
Growth	2	Ln (leaf area) = 3.93 + 0.12*WAE Ln (shoot dry weight) = 0.83+0.096* WAE	0.99 0.99	0.000 0.000	24 24	Ln (plant height) = 0.42 + 0.32*WAE Ln (shoot dry weight) = -0.41+0.3* WAE	0.89 0.91	0.000 0.000	24 24
Growth	4	Ln (leaf area) = 3.41 + 0.12*WAE Ln (shoot dry weight) = 0.55+0.087* WAE	0.98 0.98	0.000 0.000	24 24	Ln (plant height) = 0.62 + 0.28*WAE Ln (shoot dry weight) = 0.26* WAE	0.89 0.91	0.000 0.000	24 24
Growth	6	Ln (leaf area) = 3.2 + 0.12*WAE Ln (shoot dry weight) = 0.44 + 0.079* WAE	0.99 0.99	0.000 0.000	24 24	Ln (plant height) = -0.14 + 0.24*WAE Ln (shoot dry weight) = 0.72 + 0.26* WAE	0.92 0.92	0.000 0.000	24 24
Growth	8	Ln (leaf area) = 2.97 + 0.12*WAE Ln (shoot dry weight) = 0.35 + 0.074* WAE	0.98 0.99	0.000 0.000	24 24	Ln (plant height) = 0.84 + 0.24*WAE Ln (shoot dry weight) = 0.22* WAE	0.90 0.92	0.000 0.000	24 24
Growth	10	Ln (leaf area) = 2.89 + 0.11*WAE Ln (shoot dry weight) = 0.32 + 0.068* WAE	0.98 0.98	0.000 0.000	24 24	Ln (plant height) = 0.88 + 0.23*WAE Ln (shoot dry weight) = 0.63 + 0.21* WAE	0.92 0.93	0.000 0.000	24 24
Growth	12	Ln (leaf area) = 2.7 + 0.12*WAE Ln (shoot dry weight) = 0.22 + 0.071* WAE	0.98 0.98	0.000 0.000	24 24	Ln (plant height) = 0.7 + 0.23*WAE Ln (shoot dry weight) = 0.21* WAE	0.92 0.93	0.000 0.000	24 24

WAE = week after emergence.

the effects were interdependent (Table **1**). When water stress started at early vegetative stage, shoot dry weight of cowpea decreased at a slow rate up to a density of 8 plants per pot and remained constant thereafter. When stress started at flowering and under no water stress, shoots dry weight was dropped sharply with density as a result of reduction in leaf area absolute and relative growth rates (Fig. **1a**, Tables **1** and **2**). Long low water stress increased the intensity of intra-specific competition (Table **3**). The relationship between leaf length and width of cowpea and leaf area was linear and independent of water stress and seedling density (R^2 = 0.93, P ≤0.001).

Both low water and density stresses affected cowpea pod and seed yield. With no water stress, pod dry weight increased by 5.5 and 1.76 times and number of seeds/plant by 7 and 4 times compared to stress started at early vegetative and flowering stage, respectively. Cowpea pod dry weight and number of seeds per plant were inversely related to seedling density (Fig. **1b** and **c**). The differences in water stress effect were higher at lower planting densities. The relationship between seedling densities and number of seeds per plant is negatively correlated (R^2 = 0.99, 0.91 and 0.98, P< 0.001, under water stress at vegetative and flowering stages, and no stress, respectively).

Neither low water stress nor high seedling densities had significant effect on seed weight. Number of seeds per pot was highly correlated with pod dry weight (R^2= 0.97, P<0.001) while pod dry weight was associated with seeds per pod (R^2 = 0.91, No. 72) and somehow to pod length (R^2 = 0.73).

3.1.2. Effect on A. retroflexus

Water and seedling density stresses significantly reduced initial absolute plant height, shoot dry weight and relative growth rate of *A. retroflexus* (Tables **1** and **2**). Water stress started at vegetative growth stage resulted in the lowest weed RGR. The variation in growth rates due to water and density stresses over growing season resulted in differences in plant height and shoot dry weight of the weed (Fig. **2a** and **b**). Intraspecific competition coefficients were dependent on water treatments and increased with prolonged water stress over the growing season (Table **3**). Shoot dry weight of *A. retroflexus* was highly associated with its leaf area at early growth stages (R^2 = 0.99). However, under all water treatments, shoot dry weight of *A. retroflexus* was negatively correlated with the intensity of intraspecific competition.

Water stress imposed at growth stages and seedling density significantly affected inflorescence dry weight of *A. retroflexus* (Fig. **2c** and Table **1**). Water stress at vegetative and flowering stages increased intensity of the weed intraspecific competition by about 3.2 and 2.7 times, respectively, compared with no water stress. Inflorescence dry weight obtained under optimum conditions was about 2 and 1.5 times higher than that when stress started at early and at flowering stages, respectively.

The effect of both water stress and seedling density on inflorescence dry weight was interdependent (Fig. **2c**). Differences in water effect were higher at lower than at higher densities. The inverse model was fitted for all three water conditions with R^2 ranging from 0.94 to 0.97 (Table **1**). However, inflorescence dry weight was associated with stem dry weight and number of reproductive branches per plant (R^2 = 0.91).

3.2. Experiment 2. Plant Growth Analysis of Cowpea and *A. retroflexus*

Analysis of different growth parameters of both species are shown in Table **4**. Relative elongation rate of *A. retroflexus* was 4 times higher than that of cowpea. Cowpea grew taller than *A. retroflexus* only during the first three weeks after emergence (Fig. **3a**). Two-third of *A. retroflexus* height elongation occurred after its leaf area and root growth were ceased (Fig. **3a** and Table **5**).

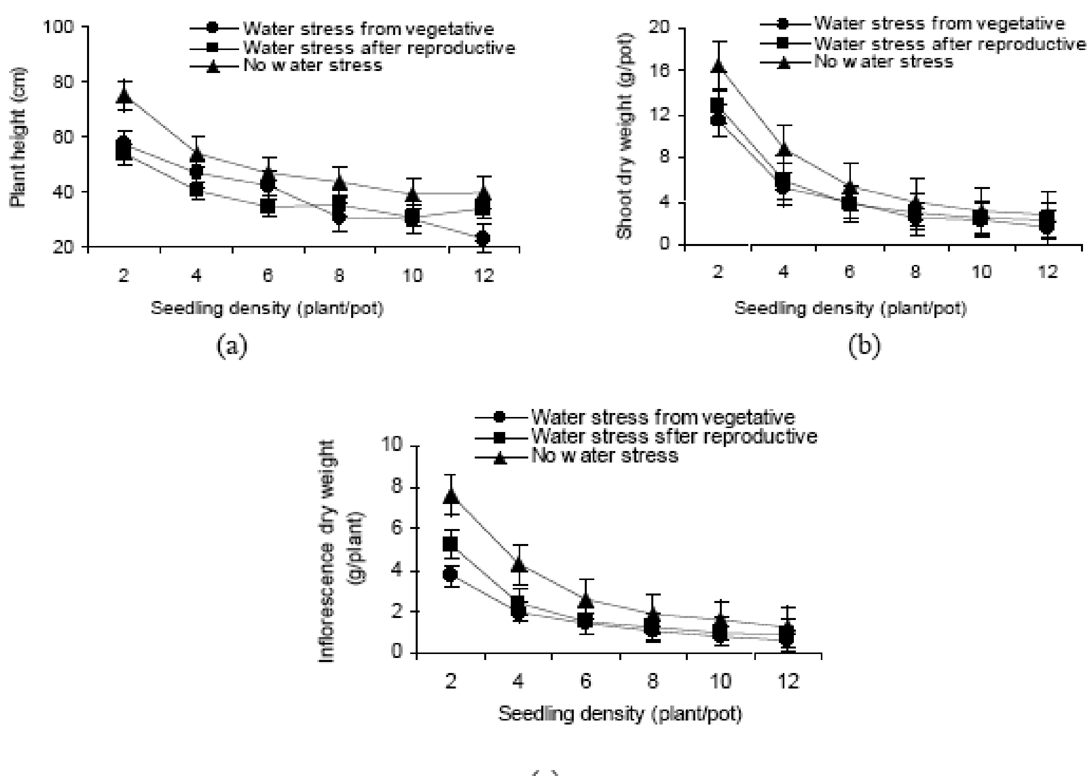

Fig. (2). Effect of different levels of water stress and seedlings density on **a**) plant height, **b**) shoot dry weight and **c**) inflorescence dry weight of *A. retroflexus*. Error bars indicate SE of the means.