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REGULAR ARTICLE

Weed biology and growth analysis of *Celosia argentea* L., a weed associated with groundnut and finger millet crops in southern India

Gogga M. Ravindra[1], Shankarappa Sridhara[2*], Gubbi K.Girijesh[2], Hooradahalli V.Nanjappa[1]

[1] Department of Agronomy, College of Agriculture, University of Agricultural Sciences, GKVK, Bangalore-560 065, India.
[2] Department of Agronomy, College of Agriculture, Shimoga-577 204, India.
* Corresponding author: Shankarappa Sridhara, E-mail: sridharas1968@yahoo.in

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ABSTRACT

An experiment was conducted to study the weed biology of *Celosia argentea* L., during the rainy season of 2007 at Navile, Shimoga, India (14°1′N, 75°42′E and 650 m AMSL). The results showed that more leaves (44.8 ± 1.17) and branches (18.2 ± 0.52) and taller plants (107.5 ± 3.40) were present at plant maturity of *C. argentea*. The plant took 5.87 ± 0.25 d, 6.00 ± 0.49 d and 61.10 ± 1.76 d for germination, branching and maturity respectively. At maturity highest dry matter (DM) accumulation was observed in the stem (9.81 ± 0.22 g plant^{-1}) compared to other plant parts. Higher absolute growth rate (AGR) (0.51 ± 0.01 g plant^{-1} d^{-1}), net assimilation rate (NAR) (0.03 ± 0.00 g cm^{-2} d^{-1}), relative growth rate (RGR) (0.07 ± 0.00 g g^{-1} d^{-1}) and crop growth rate (CGR) (g m^{-2}d^{-1}) were observed between 30 and 50 days after sowing (DAS). Leaf area duration (LAD) of 2.70 ± 0.036 d was observed between 50-70 DAS with a total LAD of 4.83 d. At maturity *C. argentea* had a leaf area of 36.25 ± 0.79 cm^2 plant^{-1}. The heat use efficiency of *Celosia* was 0.03 g GDD^{-1}. Dry matter accumulation in *C. argentea* complied with different mathematical models such as the logistic, Richards and Gompertz curves.

Key Words: *weed biology; growth analysis; Celosia argentea L.*.

INTRODUCTION

Knowledge of weed biology is essential for the development of economic and environmentally acceptable weed management systems (Bhowmik, 1997). To establish weed control strategies it is important to recognize the natural strategies of major weeds infesting a crop. Weed biology relates to plant attributes such as morphology, seed dormancy and germination, growth physiology, competitive ability and reproductive biology. *Celosia argentea* L. is an herbaceous annual weed found in many crops such as Groundnut (*Arachis hypogaea* L., Finger Millet (*Eleusine coracana* L. Gaertn) and Maize (*Zea mays* L.). It is erect plant and grows to a height of 1.0 to 1.6 m under favorable condition. It has numerous lateral roots below the soil surface. These enable it to efficiently absorb nutrients from the soil. Lately it has become a troublesome weed to control in field crops as it emerges several times during a cropping cycle and escapes weed control measures. It produces 2,000 to 3,000 seed plant^{-1} which add to the soil seed bank. There are few published studies on the biology of *C. argentea*. Understanding weed biology with respect to different environmental, edaphic and management factors offers a key to improved weed management strategies such as different stages of susceptibility for weed control. Analysis of quantitative aspects of whole plants can be conducted using growth analysis techniques. In plant growth analysis, attention has recently been paid to the functional approach using mathematical models to empirically describe plant growth. The models describe plant growth by curve smoothing and generally include final plant size as an essential parameter. This approach gives a clear perception of time dependent phenomenon of plant growth. Additionally it can derive relative growth and unit leaf rates at any point in time (Richards, 1969; Thornley, 1976). With this background, in this paper an effort is made to fit the best models to describe total DM production of *C. argentea*. The objective of this work was to investigate the weed biology, different growth rates and growth components of *C. argentea*.

MATERIALS AND METHODS

The experiment was conducted at the College of Agriculture, Shimoga, during the *Kharif* (Rainey season) season of 2007. One hundred earthen pots (45 cm diameter × 30 cm deep) were sown with *C. argentea* seed after filling with a soil:sand (2:1) potting mixture. Due to high natural soil fertility no fertilizer was added. Sufficient seed was sown so 3 or more seedlings would emerge pot^{-1}. Eight days after sowing (DAS), seedlings were thinned to 3 plants pot^{-1}. Pots (10 harvest^{-1} for DM accumulation study) were randomly arranged in a green house.

The maximum temperature during plant growth was 28.5 + 3 °C during early growth and 29.8 + 1 °C during final growth stages. The minimum temperatures ranged from 18.2 to 20.1 °C. Pots were watered every 2 d. Data was recorded on days to germination, branching and flowering. Of the 100 pots 70 were used for determination of above ground DM accumulation. For growth analysis, 7 harvests were taken at 10 d intervals. The first harvest was taken at 10 DAS. At each harvest, plants were divided into their different parts and dry weights recorded after oven drying at 85 °C for 48 h. Leaf area was measured by the disc method of Islam and Paul (1986). From the dry weights and leaf area data the growth attributes absolute growth rate (AGR), net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) and leaf area duration (LAD) were calculated between successive harvests using the formula proposed by Radford (1967). The remaining 30 pots were used to record observations such as plant height, branches plant^{-1}, leaves plant^{-1} and leaf area plant^{-1}. At maturity the number of seed heads plant^{-1}, seeds comb^{-1} and seed plant^{-1} were recorded. Data are reported as mean ± SE. The above ground DM production was modeled by curve fitting. The logistic, Richards and Gompertz polynomial functions were fitted to total DM against respective DAS. Heat use efficiency of *C. argentea* was assessed by regressing above ground biomass against accumulated heat units above a base temperature of 10 °C.

RESULTS AND DISCUSSION

Table 1 shows that germination of *C. argentea* seed started at 3 DAS and continued up to 8 DAS. Branching started at 10 DAS and flowering commenced at 20 DAS, the plant continued to flower until 40 DAS. Some plants started to mature as early as 44 DAS and continued up to 80 DAS. Most viable weed seeds germinate early, immediately after sowing, and germination continues for some time (Renton, et al., 2006). The prolonged germination of *C. argentea* helps the plant survive and escape early season weed management in the field. In the pots the number of leaves produced, the increase in plant height and the number of branches produced by *C. argentea* at different DAS was studied (Table 2). During initial growth the number of leaves was 2.7 ± 0.3 and the maximum was 44.8 ± 1.2 at maturity. *Celosia argentea* continued to increase in height from emergence to maturity. Branch number showed a similar trend from 16 DAS to maturity. Leaf area plant^{-1} of *C. argentea* increased from 10 to 70 DAS. Leaf area was highest (36.3 ± 0.8 cm^2 plant^{-1}) at 70 DAS and lowest at (1.2 ± 0.1 cm^2 plant^{-1}) at 10 DAS. A high rate of leaf production, plant height increase and leaf area expansion was observed between 30 and 50 DAS, hence control or management of *C. argentea* before 30 d would help to reduce crop weed competition in the field.

Table 1. Time taken (d) for germination and to attain the growth stages of branching, flowering and maturity in *Celosia argentea*.

Indices	Germination	Branching	Flowering	Maturity
Mean	5.8 ± 0.25 (78.9 ± 3.36)*	16.0 ± 0.49 (208.8 ± 6.11)	28.3 ± 1.12 (385.8 ± 16.53)	61.1 ± 1.76 (852.2 ± 25.28)
Minimum	3.0 (42.2)	10.0 (151)	20.0 (261.05)	44.0 (607.2)
Maximum	8.0 (107.5)	20.0 (261.1)	40.0 (552.3)	80.0 (1121.3)

*Values in the parenthesis are thermal time (TT or GDD) above a base temperature of 10 °C.

Table 2. The Number of leaves, plant height (cm), number of branches, leaf area and leaf area index of *Celosia argentea* at different times after sowing.

Days after sowing	Number of leaves	Plant height (cm)	Number of Branches	Leaf area (cm^2 plant^{-1})	LAI
10	2.7 ± 0.31	3.4 ± 0.34	-	1.2 ± 0.12	-
20	8.2 ± 0.44	6.5 ± 0.33	3.2 ± 0.37	3.8 ± 0.26	0.01 ± 0.001
30	18.6 ± 0.80	14.8 ± 0.58	5.3 ± 0.34	10.5 ± 0.51	0.03 ± 0.001
40	27.7 ± 1.08	52.5 ± 1.09	11.9 ± 0.36	18.2 ± 0.64	0.05 ± 0.002
50	28.7 ± 1.06	71.3 ± 2.72	13.4 ± 0.69	29.8 ± 0.82	0.08 ± 0.002
60	40.8 ± 1.00	93.2 ± 2.06	14.0 ± 0.53	34.4 ± 0.91	0.09 ± 0.002
Maturity	44.8 ± 1.17	107.5 ± 3.40	18.2 ± 0.52	36.3 ± 0.79	0.10 ± 0.002
Mean	24.5	49.9	9.4	19.2	0.05
SE ±	1.05	2.82	0.45	0.96	0.002
Range	2 – 56	1 – 150	0 – 24	0.5 – 46.15	0.001 – 0.126

The leaf area index (LAI) was maximum (0.10 ± 0.002) at 70 DAS. A lower (0.01 ± 0.001) LAI was recorded at 10 DAS. The LAI ranged from 0.001 to 0.126 with a mean of 0.05. Increased LAI occurred due to an increase in leaf production as well as increased leaf expansion. The low initial LAI in early growth may be due to a lower rate of cell division and expansion. A reduction in LAI after 70 DAS was due to rapid leaf senescence and a reduction in leaves plant^{-1}. The LAD of *C. argentea* ranged from 0.48 to 3.07 d (mean 1.61 d). The persistence of leaf area was longer between 30-50 DAS. This prolonged leaf duration helped the production of more photosynthate for longer giving profuse *C. argentea* growth and increasing the weed's competitive ability.

The rate of height increase, leaf production and branches are shown in Figure 1. Plant height increased by 1.94 cm day^{-1}, leaf production was 0.72 leaves d^{-1} and branch production was 0.29 branches day^{-1}. This increased growth rate makes the weed more competitive with crops, and with other weeds, for resources like light, water and nutrients. In this work the rate of increase in growth conformed with the results of Ayeni (1984) who reported the rate of increase in height, leaf production and tillers in spear grass (*Achnatherum calamagrostis L.)*.

Above ground DM accumulation of *Celosia argentea* followed a sigmoid curve (Table 3). Generally total DM production of *C. argentea* was from 0.11 to 25.42 g plant 1 irrespective of growth stage. At maturity maximum DM accumulated was 9.8 ± 0.22 g plant^{-1} in stems 7.25 ± 0.16g plant^{-1} in leaf and 5.34 ± 0.19 g plant^{-1} in the flower head. The increase in total DM was due to increased LAI as well as leaf persistence to give a longer LAD from emergence to maturity in *C. argentea*. Aboveground DM increased slowly during early vegetative growth but increased rapidly with age. The rapid increase in aboveground DM during later growth was due to an absence of senescence until the plant attained physiological maturity.

Figure 1. Rate of plant height increase (cm), rate of leaf production and rate of branch production in *Celosia argentea*. Vertical bars indicate the respective SE.

Of above ground DM produced by *C. argentea* about 44 % was in stems, 32 % in leaves and 24 % in flower heads. These results conform with those of Costea et al. (2005) who reported similar DM accumulation trends in weeds from the Amaranthaceae. Khalid and Robert (2004) also reported the growth pattern of several weeds was exponential.

Different growth indices like AGR, NAR, CGR and RGR were calculated and are presented in Table 4. The maximum AGR was 0.51 ± 0.01 g plant^{-1} day^{-1}, the NAR was 0.03 ± 0.00 g cm^{-2} day^{-1}, CGR was 0.05 ± 0.00 g m^{-2} day^{-1} and RGR was 0.07 ± 0.00 g g^{-1} day^{-1} recorded between 30 to 50 DAS. These growth indices tended to decline after 30-50 DAS. The decrease in the NAR after 50 DAS was attributed to a higher LAI at later growth stages. Watson (1958) and Harper (1963) attributed a decline in NAR at later stages to mutual leaf shading resulting in reduced photosynthesis. The high CGR (0.05 ± 0.00 g m^{-2} day^{-1}) between 30 to 50 DAS was due to higher DM production owing to a higher LAI. Similar growth rate results were observed in *Amaranthus palmeri* L., where the maximum growth rate was recorded between 30 to 50 DAS (Horak and Loughin, 2000).

Heat use efficiency above a base temperature of 10 °C of *Celosia argentea* was calculated and is presented in Figure 2. Total DM accumulation was positively correlated with growing degree days or thermal time.

Table 3. Dry matter accumulation (g $plant^{-1}$) pattern of *Celosia argentea*.

Days after Sowing	Stem	Leaf	Head	Total
10	0.03 ± 0.00	0.24 ± 0.02	-	0.28 ± 0.02
20	0.32 ± 0.20	0.77 ± 0.05	-	1.08 ± 0.06
30	1.19 ± 0.06	2.10 ± 0.10	-	3.29 ± 0.14
40	2.91 ± 0.08	3.65 ± 0.13	0.86 ± 0.03	7.42 ± 0.16
50	4.79 ± 0.11	5.96 ± 0.16	2.67 ± 0.10	13.42 ± 0.19
60	7.19 ± 0.11	6.88 ± 0.18	4.22 ± 0.13	18.29 ± 0.26
Maturity	9.81 ± 0.22	7.25 ± 0.16	5.34 ± 0.19	22.40 ± 0.28
Mean	3.75	3.84	3.27	9.45
SE ±	0.24	0.19	0.17	0.56
Range	0.01 – 11.25	0.10 – 9.23	0.51 – 6.84	0.11 – 25.42

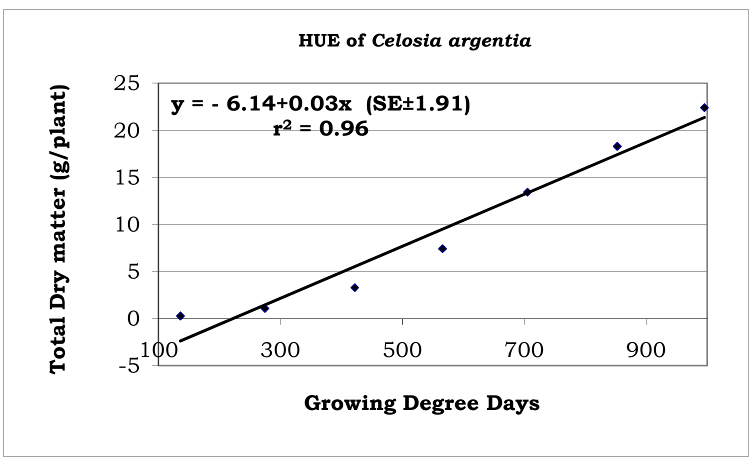

Figure 2. Heat use efficiency of *Celosia argentea*.

At maturity *C. argentea* produced 12.97 ± 0.83 seed heads with 52.67 ± 3.52 seeds seed $head^{-1}$, which gave 690.1 ± 70.9 seeds $plant^{-1}$ and a 1,000 seed weight of 6.67 ± 0.32 g (Table 5). The high seed production potential of *C. argentea* makes weed emergence recurrent by contributing to the weed seed bank. Shrestha et al. (2002) reported that the seed production potential of weeds increases infestation by the same weed in the future days.

Different mathematical models were fitted to *C. argentea* DM accumulation. In describing DMP, sigmoid functions fitted the data close to the observed values. Total DM produced by *C. argentea* followed the logistic, Richards and Gompretz models with appreciable regression coefficients (Figure 3). The Richard's model gave the best fit by estimating total DMP 99%

near to actual values. The next best models to describe DMP were the Gompertz and logistic curve which fitted DMP to 98% of the observed values. A similar, better fit of the Richards function was observed in describing wheat (*Triticum aestivum* L.) DMP (Venus and Causton, 1979) and rice (*Oryza sativa* L.) DMP (Srinivasan et al., 1986). Torner et al. (2000) reported similar results while studying growth of different weed species.

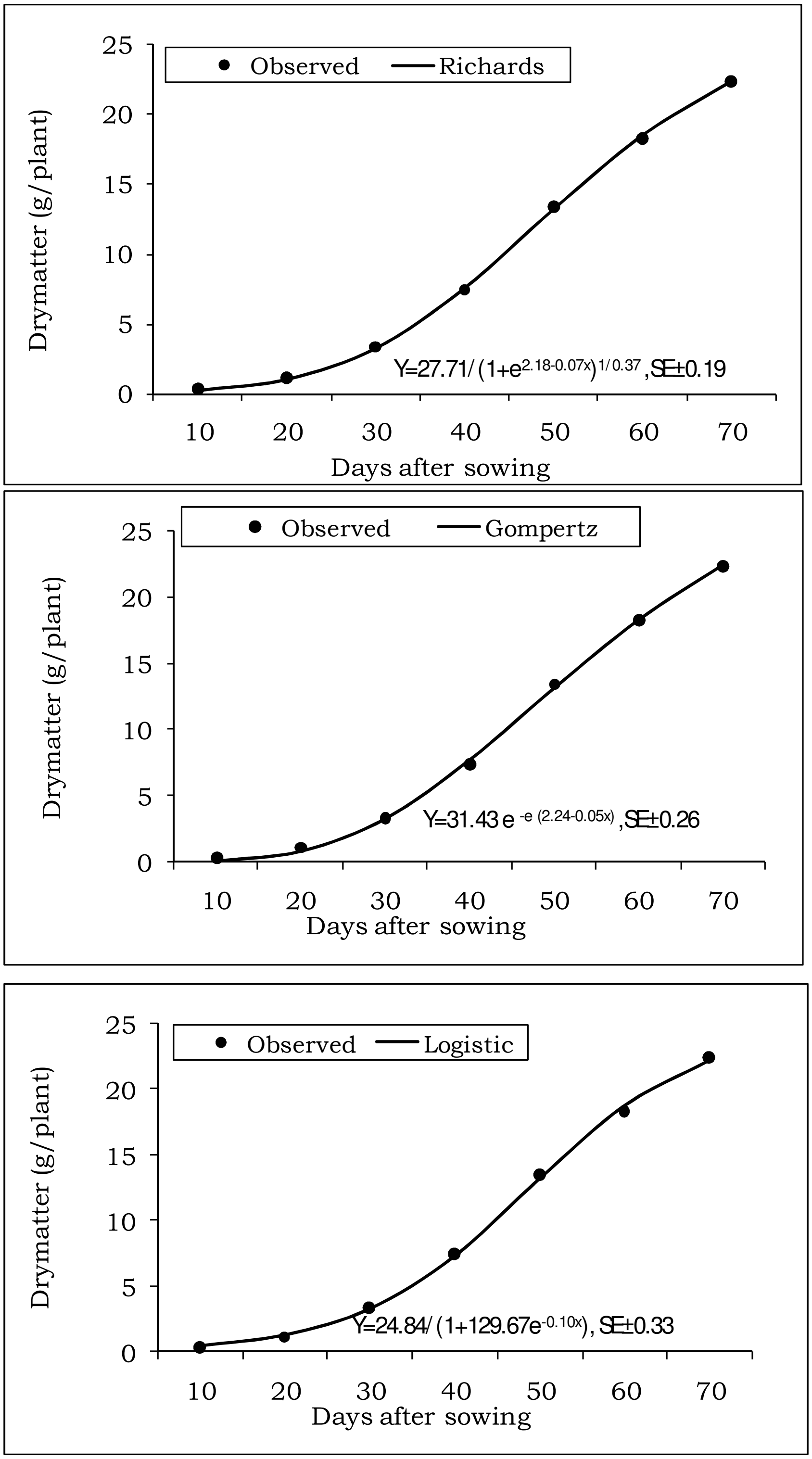

Figure 3. Different growth models fitted to dry matter accumulation and days after sowing.

It can be concluded from that controlling the weed *C. argentea* before it attains 30 d would be useful in reducing crop weed competition in the field condition as the rate of growth and DM accumulation was greatest during this period.

Table 4. Absolute growth rate (AGR), net assimilation rate (NAR), relative growth rate (RGR), crop growth rate (CGR) and leaf area duration (LAD) of *Celosia argentea* between 0-30, 30-50 and 50-70 d after sowing

DAS	AGR (g plant^{-1} day^{-1})	NAR (g cm^{-2} day^{-1})	RGR (g g^{-1} day^{-1})	CGR (g m^{-2} day^{-1})	LAD (d)
0 - 30	0.15 ± 0.01	0.02 ± 0.00	0.13 ± 0.00	0.01 ± 0.00	0.48 ± 0.021
30 - 50	0.51 ± 0.01	0.03 ± 0.00	0.07 ± 0.00	0.05 ± 0.00	1.65 ± 0.040
50 - 70	0.45 ± 0.02	0.01 ± 0.00	0.03 ± 0.00	0.04 ± 0.00	2.70 ± 0.036
Mean	0.37	0.02	0.07	0.03	1.61
SE ±	0.018	0.018	0.004	0.005	0.009
Range	0.08 – 0.66	0.01 – 0.7	0.01 – 0.18	0.01 – 0.06	0.2 – 3.07

Table 5. Plant characteristics of *Celosia argentea* at maturity

Parameter	Mean ± SE	Range
Seed heads plant^{-1}	13.0 ± 0.83	5 – 20
Seed seedhead^{-1}	52.7 ± 3.52	24 – 95
Seeds plant^{-1}	690.1 ± 70.87	200 – 1672
1000 seed weight (g)	6.7 ± 0.32	4 – 10

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