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# Impact of weed management practices on simulation of dry matter in maize through empirical models

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## ABSTRACT

**A field experiment was conducted during *kharif* 2007 at the Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore, under irrigated conditions to know the pattern of dry matter production in maize using empirical models under weed management practices. Empirical models simulated the crop growth (dry matter production) of maize by 98% indicating that competition of weed types did not alter the pattern of growth of maize, but cumulatively affected the total dry matter at harvest, where as, the linear function predicted the crop growth by 92 to 94%. Differentiating quadratic and linear functions indicated that dry matter production efficiency (DMPE) were improved by 34 to 46% in hand weeding or atrazine treatments due to elimination of weed competition over unweeded control. Competition of grassy weeds (in 2,4-D EE treatment) lowered the DMPE by 24% over atrazine treatment with less weed competition, while competition from broad leaf weeds and sedge lowered the DMPE by 22%. Thus grasses showed higher competitive ability, followed by broad leaf weeds and sedges.**

**Key words :** Maize, Empirical models, Weed management practices, Dry matter production efficiency

Weeds offer stiff competition for resources in maize during initial stage in view of wide row spacing and affect the growth and yield, apart utilizing considerable quantity of nutrients at the cost of crop (Ramachandra Prasad *et al.* 1993). Traditional method of growth analysis to elucidate causes for yield variation based on the logical sequences of crop developmental processes is still in vogue (Watson 1952). However, this classical method is modified by a dynamic functional approach using mathematical relationship which integrates the whole growth processes (Hunt 1990). Using this functional relationship, crop growth modeling is often attempted to know the crop growth pattern under various factors of production and to quantity the influence of factors of production on crop growth. In this direction, sigmoidal functions namely Richards, Logistic and Gompertz were used to describe crop growth in crops earlier (Porter 1989, Ramachandra Prasad and Shivashankar 1992, Ramachandra Prasad *et al.* 1992, 1993). Some studies have indicated the better suitability of Richards function in describing total crop growth in wheat (Venus and Causton 1979) and maize (Causton and Venus 1981). Subsequently in maize, Richards and Gompertz models in cv. *Deccan hybrid* and Richards for vegetative and logistic for reproductive phase in cv. *Deccan 101* showed better goodness of fit in describing the crop growth (Ramachandra Prasad *et al.* 1992, Ramachandra Prasad and Shivashankar 1992). In sesamum, Praveen Rao (1990) observed good fit in describing dry matter using logistic model, whereas in rice, Srinivasan *et al.* (1986) observed better fit in describing dry matter using Richards function in different cultivars. In winged bean, Well and Belmont (1991) described dry matter production with high goodness of fit using logistic model. However in the present study, an effort has been made to know the variation in pattern of dry matter production and to quantify the ill effect due to weed types' competition under weed management practices through functional models.

## MATERIALS AND METHODS

The Steady was carried out on Alfisols (red sandy loam soil) at field unit of All India Coordinated Research Programme on Weed Control, Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore during *kharif* 2007. The experiment consisted of six treatments laid out as RCBD with four replications. Only four weed management practices namely atrazine 0.75 kg/ha (eliminating competition of grasses and broad leaf weeds), 2,4-D EE 0.8 kg/ha (eliminating competition of broad leaf weeds and sedge), hand weeding (two times at 20 & 40 days after sowing, elimination of competition of all weed types) and unweeded control (competition from all weed types- sedges, grasses and broad leaf weeds) were selected to work out the pattern of crop growth in terms of total dry matter production and to quantify the ill effect of competition from weed types mediated through weed management practices. Cv. *NAC 6004* was raised at a common fertilizer dose of 100 kg N, 75 kg $P_2O_5$ and 38 kg $K_2O$/ha and spacing of 60 cm between rows and 30 cm between plants. The gross and net plot sizes were 6.0 x 6.0 m and 3.6 X 4.8 m, respectively. Periodical total dry matter production (g/plant) recorded at 10 days interval from 10 to 120 DAS (at harvest), was used for fitting the cob growth data through the following models. Here for convenience sake, quadratic and linear model was differentiated to work out dry matter production efficiency (DMPE), which represent rate of increase in dry matter production per plant per day (g/plant/day).

Richards: $Y_{DMP} = a\{1 + \exp.^{(b-ct)}\}^{1/d}$

Logistic: $Y_{DMP} = a\{1 + b\exp.^{ct}\}^{-1}$

Gompertz: $Y_{DMP} = a\exp.\{-\exp.^{(b-ct)}\}$

Quadratic: $Y_{DMP} = a + bt + ct^2$

Linear: $Y_{DMP} = a + bt$

Where $Y_{DMP}$ = Total dry matter production, g/plant, t = days after sowing, a, b, c and d are constants to be worked out.

By differentiating quadratic and linear models, dry matter production efficiency (DMPE) i.e., rate of dry matter production per plant per day, was worked out for different stages as follows:

Quadratic model, DMPE, g/plant/day = $\eth_{DMP}/\eth t = b + 2cx$
Linear model, DMPE, g/plant/day = $\eth_{DMP}/\eth t = b$

The models' sensitivity was assessed by working out standard error (SE) and root mean squared deviation (RMSD), apart from estimating coefficient of determination ($R^2$).

$$SE = \frac{\Sigma (O-P)^2}{\text{No. of observation}}$$

RMSD = $\sqrt{SE}$; Where O = Observed data,
P = Predicted value

## RESULTS AND DISCUSSION

### Weed flora

Major weed flora observed from initial stages in the experimental plot was *Cyperus rotundus* Linn. (a sedge); *Echinochloa colona* Linn., *Digitaria marginata* Link., *Chloris barbata* Linn., *Eleusine indica* Gaertn., *Eragrostis pilosa* Beauv., *Dactyloctenium aegyptium* (L.) P. Beauv., *Cynodon dactylon* (L.) (among grasses), *Borreria articularis* Linn., *Ageratum conyzoides* Linn., *Commelina benghalensis* Linn., *Acanthospermum hispidum* DC., *Leucas aspera* (Willd.) Link. and *Portulaca oleracea* Linn. (among broad leaf weeds). Atrazine gave good control of grasses (15.5 grasses/m$^2$) and broad leaf weeds (11.7 weeds/m$^2$) and compared similar (38.7 total weeds/m$^2$) to that of hand weeding (6.5 grasses/m$^2$, 13.5 broad leaf weeds/m$^2$, 38.5 total weeds/m$^2$), while 2,4-D EE controlled broad leaf weeds effectively (0.5 weeds/m$^2$). Unweeded control showed the dominance of grasses (77.4 weeds/m$^2$), followed by sedge (38.2/m$^2$) and broad leaf weeds (25.2/m$^2$) (140.6 total weeds/m$^2$).

### Dry matter production

In maize, Richards, Logistic and Gompertz simulated the total dry matter production by 98%, followed by second order polynomial, Quadratic, which showed a prediction of 94 to 96% under all four weed management practices with varying weed types competition. Thus the pattern of crop growth of maize was similar under all weed management practices as explained by the curvilinear models suggesting that weed competition will not affect the time dependent crop growth, but the cumulative negative effect was seen on lowering the total dry matter production at harvest. The total dry matter production in atrazine treatment was 352.7 g/plant as against total DMP of 291.3 g/plant in 2,4-D EE treatment and 233.7 g/plant in unweeded control. This clearly indicated a cumulative negative effect of all types of weeds' competition by lowering total DMP by 34% as observed in unweeded control, although pattern of fitting the data was similar at all weed management practices.

These symmetrical models also showed lower error component as compared to polynomial model simulating the crop growth meaningfully and nearness to the actual data, as also explained by Ramachandra Prasad *et al.* (1992) in maize and Ramachandra Prasad *et al.* (1996) in sunflower.

To quantify the ill effect of weed types competition in limiting the dry matter production of maize, linear model was fitted separately for vegetative and reproductive period and was compared with the fitting of data with entire crop growth period. The linear model simulated the dry matter production with higher $R^2$ values during reproductive stage (92%) than during vegetative stage (76 to 87%) in treatments receiving atrazine, hand weeding and 2,4-D EE, while under unweeded control condition (simulating competition of all weed types with maize throughout the crop growth), similar simulation of the dry matter production during vegetative (85%) and reproductive stages (83%) was observed. In addition total dry matter production was simulated by linear model to an extent of 92 to 94% under all the weed management practices, when dry matter production was considered for entire crop growth period. The biological worthiness of the

**Table 1. Empirical models depicting course of crop growth (dry matter, DMP, g/plant) in maize as influenced by weed management practices during *kharif* 2007 at UAS, Hebbal, Bangalore**

| WMP / Models | Functional Models | $R^2$ | SE | RMSD |
|---|---|---|---|---|
| **Atrazine 0.75 kg/ha** | **3 DAS Elimination of competition from grasses and broad leaf weeds** | | | |
| Richards | $DMP = 376.88/[1+ \exp(4.28-0.07\,t)^{1/0.64}]$ | 0.98** | 7.40 | 37.20 |
| Logistic | $DMP = 368.27/[1+ 312.06 \exp(-0.084\,t)]$ | 0.98** | 7.42 | 6.72 |
| Gompertz | $DMP = 404.08 \exp[-\exp(3.00-0.048\,t)]$ | 0.98** | 8.96 | 7.90 |
| Quadratic | $DMP = -46.43 + 1.88\,t + 0.025\,t^2$ | 0.96** | 31.62 | 26.98 |
| Linear | $DMP = -98.19 + 4.26\,t$ | 0.94** | 35.59 | 32.20 |
| **2,4-D EE 0.8 kg/ha** | **18 DAS Elimination of broad leaf weeds** | | | |
| Richards | $DMP = 306.22/[1+ \exp(6.85-0.09\,t)^{1/118}]$ | 0.98** | 4.17 | 23.66 |
| Logistic | $DMP = 309.23/[1+ 447.29 \exp(-0.087\,t)]$ | 0.98** | 4.02 | 3.56 |
| Gompertz | $DMP = 342.71 \exp[-\exp(3.13-0.050\,t)]$ | 0.98** | 8.56 | 10.49 |
| Quadratic | $DMP = -30.49 + 1.01\,t + 0.02\,t^2$ | 0.96** | 26.36 | 23.50 |
| Linear | $DMP = -85.26 + 3.54\,t$ | 0.92** | 32.25 | 29.18 |
| **Hand weeding (20 and 40 DAS)** | **Elimination of grasses, broad leaf weeds and sedge** | | | |
| Richards | $DMP = 338.37/[1+ \exp(4.90-0.078\,t)^{1/0.75}]$ | 0.98** | 4.05 | 22.41 |
| Logistic | $DMP = 333.67/[1+ 367.69 \exp(-0.087\,t)]$ | 0.98** | 4.10 | 4.10 |
| Gompertz | $DMP = 363.78 \exp[-\exp(3.105-0.050\,t)]$ | 0.98** | 6.96 | 6.29 |
| Quadratic | $DMP = -44.17 + 1.79\,t + 0.017\,t^2$ | 0.94** | 29.73 | 25.67 |
| Linear | $DMP = -89.97 + 3.908\,t$ | 0.94** | 32.89 | 29.75 |
| **Unweeded control** | **Competition from grasses, broad leaf weeds and sedge** | | | |
| Richards | $DMP = 242.49/[1+ \exp(9.17-0.122\,t)^{1/1.60}]$ | 0.98** | 4.52 | 22.40 |
| Logistic | $DMP = 247.49/[1+ 789.60 \exp(-0.09\,t)]$ | 0.98** | 4.88 | 16.37 |
| Gompertz | $DMP = 266.17 \exp[-\exp(3.58-0.056\,t)]$ | 0.98** | 8.96 | 7.95 |
| Quadratic | $DMP = -29.37 + 1.01\,t + 0.02\,t^2$ | 0.94** | 25.66 | 32.97 |
| Linear | $DMP = -70.71 + 2.91\,t$ | 0.92** | 28.75 | 26.01 |

DMP = Dry matter production, g/plant; t = time in days after sowing, $R^2$ = Coefficient of determination, SE = Standard Error, RMSD = Root mean square deviation; WMP = Weed Management Practices; ** = Significant at 0.01 probability level

model was made by differentiating the linear model under all the weed management practices. The differentiated value of the dry matter production was also termed as dry matter production efficiency (g/plant/day).

### Dry matter production efficiency

Dry matter production efficiency (DMPE) during reproductive stage was higher in atrazine treatment followed by hand weeding and 2,4-D EE, while it was pretty low in unweeded control during vegetative, reproductive and entire crop growth period. Eliminating weed competition as in atrazine and hand weeding treatment improved the dry matter production efficiency considerably (1.56 to 2.32 g/plant/day) during vegetative stage indicating the direct positive effect on enlarging sink size, as compared to unweeded control, where sink size is lowered as a result of weed competition (1.33 g/plant/day). Similarly in 2,4-D EE treatment with grassy weeds competing with maize, dry matter production efficiency was pretty low (1.66 g/plant/day), but comparable with hand weeding and better than unweeded control. During reproductive stage, treatment with atrazine had higher DMPE of 3.85 g/plant/day, followed by hand weeding (3.42 g/plant/day) and 2,4-D EE treatment (3.56 g/plant/day), while it was pretty low in unweeded control with severe weed competition (2.71 g/plant/day). Sink size was lowered due to weed competition in unweeded control and hence had lower DMPE during vegetative and reproductive stages indicating continued suppression of maize crop growth by weeds. This clearly suggested that weed competition lowered the sink size as explained by reduction in leaf area which limited the dry matter production. The rate of dry matter production as explained by the model was lowered considerably wherever, weed

**Table 2. Linear model depicting the total dry matter production and dry matter production efficiency (DMPE, g/plant/day) at different crop growth stages in maize as influenced by weed management practices**

| Weed management practices / Crop growth stages | Linear function | $R^2$ | Dry matter production efficiency, DMPE (g/plant/day) | DMPE % increase/decrease over unweeded control |
|---|---|---|---|---|
| **Atrazine 0.75 kg/ha 3 DAS** | | | | |
| Sowing to harvest | DMP = - 98.19 + 4.26 t | 0.94** | 4.26 | 46 |
| Sowing to 60 DAS | DMP = - 41.86 + 2.32 t | 0.83** | 2.32 | 74 |
| 60 DAS to harvest | DMP = - 44.49 + 3.85 t | 0.92** | 3.85 | 42 |
| **2,4-D EE 0.8 kg/ha 18 DAS** | | | | |
| Sowing to harvest | DMP = - 85.26 + 3.54 t | 0.92** | 3.54 | -6 |
| Sowing to 60 DAS | DMP = - 5.49 + 1.11t | 0.79** | 1.11 | -17 |
| 60 DAS to harvest | DMP = - 74.67 + 3.55 t | 0.90** | 3.55 | 31 |
| **Hand Weeding (20 and 40 DAS)** | | | | |
| Sowing to harvest | DMP = - 89.97 + 3.91 t | 0.94** | 3.91 | 34 |
| Sowing to 60 DAS | DMP = - 14.12 + 1.56 t | 0.76** | 1.56 | 17 |
| 60 DAS to harvest | DMP = - 33.05 + 3.42 t | 0.92** | 3.42 | 26 |
| **Unweeded control** | | | | |
| Sowing to harvest | DMP = - 70.71 + 2.91 t | 0.92** | 2.91 | - |
| Sowing to 60 DAS | DMP = - 24.36 + 1.33 t | 0.85** | 1.33 | - |
| 60 DAS to harvest | DMP = - 41.17 + 271 t | 0.83** | 2.71 | - |

DMP = Dry matter production, g/plant; t = time in days after sowing, $R^2$ = Coefficient of determination,
DAS = Days after sowing; ** = Significant at 0.01 probability level

types like grasses and broad leaf weeds' competition occurred in maize, as explained by Ramachandra Prasad (1993) in sunflower. Compared to unweeded control with all major weed types' competition, use of atrazine and hand weeding eliminating competition of all major weed types improved the dry matter production efficiency by 26 to 42% during reproductive stage and 17 to 74% during vegetative phase. This clearly suggested that weed competition during initial period limited the basic vegetative growth by lowering the sink size considerably which consequently lowered the dry matter production efficiency during reproductive phase also, as explained in the present study and also explained by Trapani *et al.* (1992).

Comparing the dry matter production from sowing to harvest, adoption of hand weeding and atrazine eliminating major weed competition, improved the dry matter production efficiency by 34 to 46% over unweeded control indicating effectiveness of weed management practices in lowering weed competition and consequential effect on the enhanced crop growth rate. Further, use of 2,4-D EE eliminating broad leaf weeds and sedges competition, improved the dry matter production efficiency by 32% over unweeded control. This indicated that grassy weed competition as observed in 2,4-D EE treatment lowered the dry matter production efficiency of maize by 22%. With elimination of broad leaf weeds and grasses in atrazine and hand weeding, dry matter production efficiency was enhanced by 12 to 24% over 2,4-D EE treatment. As observed in present study, Ramachandra Prasad (1993) observed more competition or aggressiveness of grasses in lowering the dry matter production efficiency of sunflower.

Thus present study indicated the biological utility of these models which quantify the ill effects of weed competition on crop growth rate in maize, as explained by Ramachandra Prasad *et al*. (1992) in maize and Ramachandra Prasad (1993) in sunflower.

Crop growth of maize was simulated meaningfully by 98% with empirical models Richards, Logistic, Gompertz and quadratic, while linear model predicted crop growth by 92 to 94% under all weed management practices. Dry matter production efficiency (DMPE) was improved by 25 to 34% in atrazine and hand weeding treatments causing weed free environment as compared to unweeded control. Grassy weeds' competition in 2,4-D EE treatment lowered DMPE by 10 to 12% as compared to atrazine treatment, while broad leaf weeds and sedges' competition together lowered the DMPE by 13%. Grasses showed higher competitive ability, followed by broad leaf weeds and sedges in maize.

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## REFERENCES

Causton DR and Venus JC. 1981. *The biometry of plant growth*. E. Arnold Publishers, London :16-35.

Hunt R. 1990. *Basic growth analysis Plant growth analysis for beginners*. Unwin Hyman Ltd., London, : 8-10.

Krishnamurthy K, Bommegowda A, Venugopal N, Jagannath MK, Raghunatha G and Rajashekara BG. 1973. Investigation on the varietal differences in the growth components of maize (*Zea mays* L.). *Mysore Journal of Agricultural Sciences* **7**: 377-384.

Poorter H. 1989. Plant growth analysis towards a synthesis of the classical and the functional approach. *Physiologia Plantarum* **75**: 234-244.

Praveen Rao V. 1990. Application of logistic model for predicting sesame dry matter. *Journal of Research of Andhra Pradesh Agricultural University* **18**: 172-174.

Ramachandra Prasad TV and Shivashankar K. 1992. Mathematical models to describe dry matter and cob growth in maize (*Zea mays* L.) cultivars. *Maydica* **37**: 185 to 190.

Ramachadra Prasad TV, Krishnamurthy K, Devendra R and Kailasam C. 1993. Polynomial functional models to simulate crop growth in maize (*Zea mays* L) cultivars. *Journal of Agronomy and Crop Science* **171:** 55-64.

Ramachandra Prasad TV, Krishnamurthy K and Kailasam C. 1992. Functional crop and cob growth models of maize (*Zea mays* L.) cultivars. *Journal of Agronomy and Crop Science* **168**: 208-212.

Ramachandra Prasad TV. 1993. *Weed management and crop growth modeling in sunflower and groundnut based cropping system*. Ph. D. thesis, Tamil Nadu Agricultural University, Coimbatore : 259-320.

Ramachandra Prasad TV, Palaniappan SP, Suyambulingom C and Rajagopal A. 1996. Comparison of empirical models to simulate crop growth and relative growth rate in sunflower (*Helianthus annus* L.) cultivar. *Proceedings of Indian National Science Academy Bod* **62** (2): 159-168.

Srinivasan PS, Mohan Naidu K and Ranganathan CR. 1986. Richards function, a functional growth analysis model for rice cultivars (*Oryza sativa* L.). *Current Science* **55**: 201-2003.

Trapani N, Hail AJ, Sadras VO and Vilella F. 1992. Antagonistic changes in radiation use efficiency of sunflower (*Helianthus annuus* L.). *Field Crops Research* **29**: 301-316.

Watson DJ. 1952. The physiological basis for variation in yield. *Advances in Agronomy* **4**: 101-145.

Well RR and Belmont GS. 1991. Dry matter and nitrogen accumulation and partitioning in field grown winged bean. *Experimental Agriculture* **29**: 323-328.