

GROWTH RELATIONSHIPS OF MUSTARD UNDER IRRIGATED CONDITIONS

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Abstract

Growth study of mustard (*Brassica juncea* L. cv. catlass) was studied under (triple, double and single) irrigation regimes and dry conditioned treatment in the field during 1991 and 1992. In triple application treatment, water was applied at 10% flowering, pod formation and ripening @ 5-hectare centimetres per application to the double application, water was applied at 10% flowering and pod formation @ 5- and 10-hectare centimetres, respectively and in single irrigation at 10% flowering @ 15-hectare centimetres. Above ground plant material harvested at 7-day intervals showed a substantial increase in the amount and distribution of dry matter of the plant, particularly in triple-irrigation treatment. Leaf-area index (LAI) reached a maximum just after the start of flowering and then declined. Triple application increased leaf and pod areas in maximizing crop growth rate (CGR) which increased to a maximum near early flowering and then declined. Changes in net assimilation rate (NAR) during the life cycle were associated with concomitant changes in CGR. The contribution of assimilates from leaves during the seed ripening was related to leaf-area duration (LAD) which was strongly affected by water supply. Triple application enhanced NAR, improved leaf and pod areas during seed development.

Introduction

There have been relatively few detailed studies on the growth pattern of mustard (*Brassica juncea* L.). This lack of information has recently prompted investigation in India, Australia and Britain. The growth pattern of winter rape has been described by Mendham & Scott (1975) and Mendham *et al.*, (1981) Who found that seasonal variations in seed yield were related to the amount of growth made at the onset of flowering.

Leaves are generally considered to be a principle source of photosynthate (Zeevaart, 1979), while the role of pods as a source of photosynthate in plant systems other than rape has been varied (Pate *et al.*, 1980). In *Brassica*, the translocation of fixed carbon from pod wall to seeds is rapid and pod photosynthesis contributes substantially to seed growth. According to Singh & Bhargava (1988), the photosynthetic contribution of the pod to seeds in *Brassica* is as high as 70-100%. Bilsborrow & Norton (1987) reported that the seed yield of oilseed rape is determined by the photosynthetic capacity of the pod and pod bearing branches in the phase of seed development. Plant growth is controlled by several factors where water plays a vital role and a small decrease in the availability of water to a growing plant can immediately reduce its metabolic and physiological functions and its morphological characteristics.

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Sharma & Kumar (1989) observed a significantly higher LAI (5.4), CGR (0.577 g/day), RGR (0.515 g/day), NAR (0.0076 g cm⁻²/day), and RLGR (0.864 g/day) under 0.6 IW/CPE (irrigation depth per cumulative pan-evaporation ratio) than under rainfed conditions. Prasad & Prasad (1989) reported increased LAI and CGR with increase in frequency of irrigation. Krogman & Hobbs (1975) found that irrigation slowed down the senescence of rape leaves and thereby increased the total green surface areas of the plant.

It is interesting to note that only a few physiological studies have been carried out to determine the effects of different irrigation regimes on growth and yield of *B. juncea* with no systematic studies made under the climatic conditions of North America particularly in Saskatchewan. This study was conducted in Saskatoon; a site representative of the area potentially suited to growing *B. juncea* to determine the effects of distribution and timing of irrigation on the pattern of growth.

Materials and Methods

Field study was carried out at Saskatoon, Saskatchewan during 1991 and 1992 using *B. juncea* L. CV. Cutlass, in 4.3x99.2 m plots in randomized complete-block

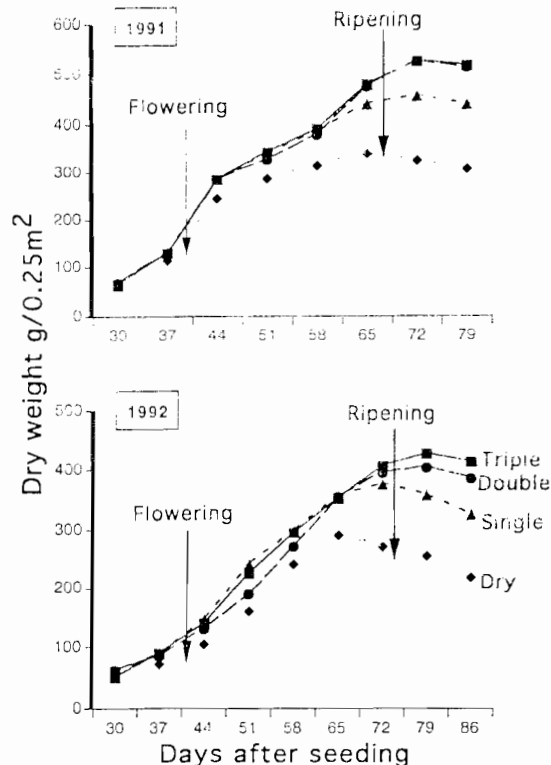


Fig. 1. Mean dry-matter accumulation of *Brassica juncea* during the growing seasons of 1991 and 1992, under triple, double, single irrigation, and dry conditions.

design (RCBD) with 6 replications. Each plot within each replication was separated by 100 cm to minimize the effect of water seepage from the irrigated plots. In addition, metal sheets of 3.5 m x 25 cm x 1.5 mm size each were inserted about 15 cm into the ground around the irrigated plots to reduce the water seepage. A powered 5-row cone seeder set for 10 cm spacing was used to seed the experiment @ 15 kg ha⁻¹ on May 22, 1991 and May 18, 1992.

Three treatments of surface irrigation (triple, double and single) in addition to one dry conditioned treatment were used. In triple application, water was applied at 10% flowering, pod formation and ripening @ 5-hectare centimetres per application. In double application, water was applied at 10% flowering and pod formation @ 5- and 10-hectare centimetres, respectively. The single irrigation was applied at 10% flowering @ 15-hectare centimetres. Water was not applied to dryland treatment, and stress was maintained by developing a gutter drainage system to remove a major proportion of the rain water. The gutter-drainage system was implemented one month after seeding by placing tar-paper gutter in between the rows of plants.

Sampling for growth parameters was started 4 weeks after seeding. Samples were taken at 7-day intervals throughout the season until 2 weeks before harvest. At each sampling time, a 0.5 x 0.5 m area was randomly selected using a metal quadrat. All plants within the quadrat were cut at the ground level and counted. All calculations were based on the number of plants 0.25 m². Leaves of 10 plants collected randomly from the main sample were separated and leaf area was measured with a recording planimeter with a continuous-belt feed. Leaves which were 50% yellowed were not included in the measurement. The pod area was also measured with the same recording planimeter used for leaf area measurements. Dry-matter determinations of the growth attributes were made at each sampling time. Ten plants were used for pod measurements. The dry-weight values of the sub-samples were converted to values per unit area on the basis of plant numbers. The values of the original data were adjusted by using the regression analysis technique to reduce variability in the growth measurements (Steel & Torrie, 1980).

Results

Irrigation had a significant influence on both the total amount of plant dry-matter (DM) produced and the pattern of its accumulation (Fig. 1). Under irrigation, the rate of accumulation of DM of the plants remained high until the late-ripening phase. The total accumulation of DM of the triple-application plants during the pod formation and ripening phase was high. The dry weight (DW) of stem during the flowering phase was a greater proportion of total DW than during the ripening phase (Table 1). The pattern of DW accumulation of the stem and leaf fraction was nearly the same under triple application and dry conditions. The fraction of leaf weight decreased towards the end of the growing seasons.

Irrigation increased ($P < 0.05$) the leaf area index (LAI) during flowering, pod formation and ripening phases over DC in both 1991 and 1992. The LAI after flowering was maintained for long period by a high level of irrigation (Fig. 2). The maximum LAIs measured in this study were 6.6 and 4.2 in 1991 and 1992,

Table 1. Dry matter accumulation fraction of above-ground components at different growth stages of *Brassica juncea* under triple, double, single irrigation and dry conditions (DC).

Growth Stages	Plant Components	% of Total Plant Dry Matter			
		Level of Water Supply			
		Triple	Double	Single	DC
1991					
Flowering	Stem	60	63	61	62
	Leaf	40	37	39	38
	Pod	-	-	-	-
Pod Formation	Stem	47	45	47	44
	Leaf	9	9	5	5
	Pod	44	46	48	51
Ripening	Stem	39	39	42	39
	Leaf	5	4	1	1
	Pod	56	57	57	60
1992					
Flowering	Stem	63	61	65	56
	Leaf	37	39	35	44
	Pod	-	-	-	-
Pod Formation	Stem	55	52	50	42
	Leaf	10	12	11	11
	Pod	35	36	39	47
Ripening	Stem	43	42	42	36
	Leaf	6	6	5	4
	Pod	51	52	53	60

Values Calculated From 6 Replications

respectively. The triple and double irrigations maintained the maximum LAI during pod formation and ripening phases. Irrigation had a significant influence on LAD (Table 2). The leaves of DC plants showed complete senescence entirely at least 1-2 weeks earlier than under irrigation conditions. Pod area (PA) was positively influenced by irrigation in the growth periods of 1991 and 1992. PA increased rapidly soon after flowering reaching a maximum when flowering ceased (Fig. 3). After flowering, increase in PA more than off-set the decline in LA thus increased the total plant photosynthetic (leaf + pod) area (PPA). The total PPA under triple- application conditions reached its maximum at the end of flowering which then declined. Irrigation especially the triple application increased the pod area duration (PAD) in both years (Table 2).

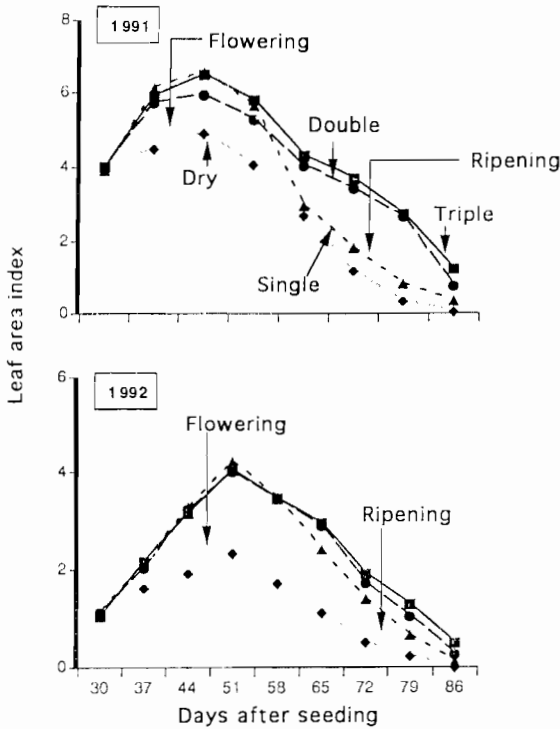


Fig. 2. Mean leaf-area index (LAI) of *Brassica juncea* during the growing seasons of 1991 and 1992, under triple, double, single application of water, and dry conditions.

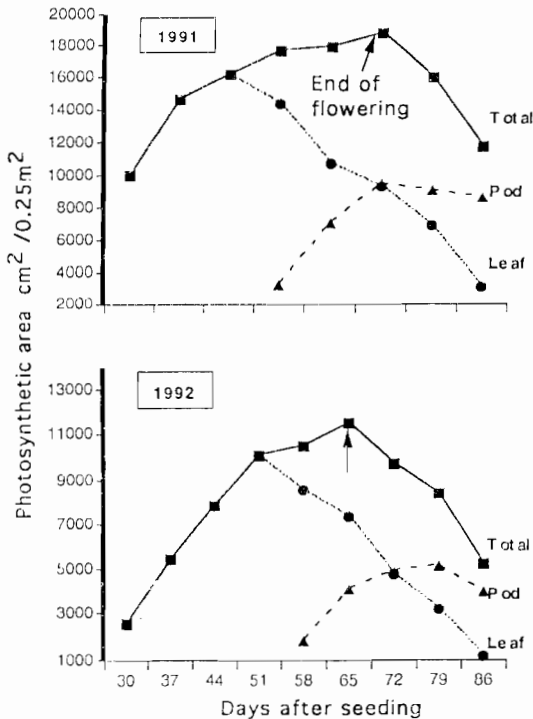


Fig. 3. Photosynthetic area of *Brassica juncea* under triple-irrigation conditions, 1991 and 1992

Table 2. Mean leaf and pod-area duration of *Brassica juncea* under triple, double, single irrigation and dry conditions (DC) 1991 and 1992.

Irrigation regimes	Leaf-area duration (m ² WK) [*]		Pod-area duration (m ² WK) ^{**}	
	1991	1992	1991	1992
Triple	55.4	34.6	22.2	12.0
Double	51.7	33.5	20.2	11.6
Single	45.8	32.1	16.7	10.5
DC	34.7	17.8	12.8	6.3
p-values [†]	0.00	0.00	0.00	0.00
LSD (0.05)	3.1	1.7	1.2	0.7

[†] Means of 48 and 54 observations during the growth period of 1991 and 1992, respectively.

^{**} Means of 30 observations

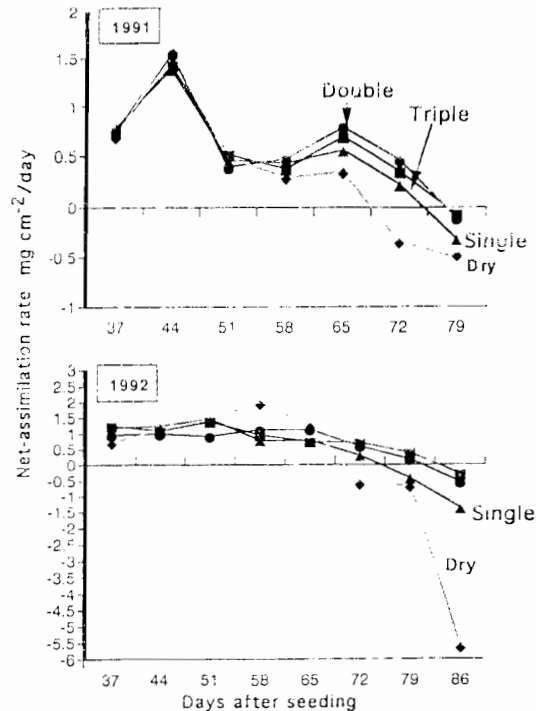


Fig. 4. Mean net-assimilation rate (NAR) of *Brassica juncea* during the growing seasons of 1991 and 1992 under triple, double, single application of water, and dry conditions.

There were significant ($P < 0.05$) differences in the NAR between irrigated and DC treatment. The NAR was high early in the growth periods, declined after flowering, increased for a short period and then declined again in 1991 (Fig. 4). In the early period of growth of 1991 and during the flowering period of 1992, NAR was higher in DC plants than in irrigated plants. Under the DC of 1991 NAR reached a peak during flowering, then declined rapidly during the ripening phase and approached a negative value. Irrigation significantly ($P < 0.05$) increased the CGR in both years and maintained it for a long period of time (Fig. 5). The CGR increased to a maximum early in flowering and declined after flowering. In 1991 under triple-application conditions, there was a rapid upswing in CGR at the end of flowering which then declined during the ripening phase.

Discussion

In the present study, the total dry matter production of *B. juncea* was increased by irrigation. A similar response to irrigation has been reported by Nathanson *et al.*, (1984), Khan & Agarwal (1988) and Garside *et al.*, (1992). The major portion of plant dry matter was produced just near the ripening which is in agreement with the findings of Khan & Agarwal (1988), who found a similar trend in DM production. High dry

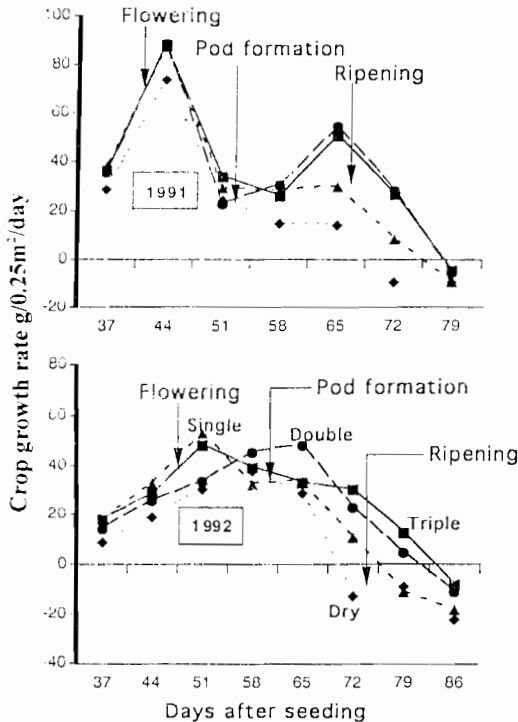


Fig.5. Mean crop-growth rate (CGR) of *Brassica juncea* during the growing seasons of 1991 and 1992 under triple, double, single application of water, and dry conditions.

matter accumulation occurs by increasing incident light interception by the increased photosynthetic tissues (leaf + pod) of the irrigated mustard plants (Wright *et al.*, 1988). The dry matter production was reduced by water stress under dry condition which could be due to decrease both in total leaf weight per plant and a decrease in number of cells per unit of leaf area (Delgado *et al.*, 1992). The changes in total dry matter accumulation during ripening phase under both the irrigation and DCs were essentially due to changes in pod (pod + seed) weight.

Both, the prolonged growing period and increased plant photosynthetic area due to irrigation, produced fully developed pods (pod + seeds). At ripening, the pods are the principal site for assimilation and stems of secondary importance in oilseed rape (Rood *et al.*, 1984). The short duration of pod growth is generally accompanied by compensatory increase in the rate of dry matter accumulation in the seed (Singh & Bhargava, 1988). LAI was maintained for a long time and a high level by irrigation after flowering which is similar to the reports of Sharma & Kumar (1989). The increase in LAI would be due to availability of high soil moisture for a long period of time during the crop growth. In the present study under triple-irrigation conditions, although leaf tissues decreased to such a low proportion of total plant DW during seed development, the concomitant decrease in CGR suggested that leaves were the most important sources of photosynthesis for seeds. Water stress at either beginning of flowering, pod formation or ripening reduced the duration of leaves in both growing seasons, presumably because of senescence hastened by drought. Drought decreased the leaf-development rate due to reduced leaf-water status which is responsible for cell expansion in plants. Cell division and cell expansion are very sensitive to moisture stress and water deficit has marked effect on LA (Turner & Begg, 1981). After flowering, increased PA more than offset the decline in LA, thereby, increasing overall plant photosynthetic capacity, which was consistent with the increase in pod-surface area and LAI in *Brassica napus* (Clarke & Simpson, 1978) and in *B. juncea*, *B. campestris*, *B. carinata* and *B. napus* (Singh & Bhargava, 1988). Maximum LAI near the start of flowering influence both size and nutritional status of plants where both the factors could influence pod setting. Wright *et al.*, (1988) have shown that maximum LAI's are associated with high numbers of pods per plant which combined with long LAD produce high final seed yields.

The increase in NAR in dry conditioned plants was probably attributable to the decreased LAI which reduced mutual shading of leaves, and exposed them to more sunlight, thus maximizing NAR. This indicates that plants under a short period of water stress are capable of sustaining the process of photosynthesis through maximum interception of solar radiation. However, under prolonged water stress plants fail to sustain optimal LAI due to senescence of leaves, and NAR declines. This is in agreement with the findings of Sharma & Kumar (1989) who reported that a decline in NAR under DC may be attributed to increased senescence of leaves by reducing photosynthetic rate. The decrease in NAR during the period of maximum flowering is related to the inability of the flower to attract large quantities of assimilates during the vital period of seed setting (Keiller & Morgan, 1988). The most important feature of NAR values after flowering was their tendency to increase for short period before maturity, particularly in irrigated material. The increase in NAR in *B. juncea* is

presumably due to: a) translocation of stored carbohydrates from roots to tops, b) pod photosynthesis and c) an increase in photosynthetic activity.

The increase in CGR was presumably due to more availability of nutrients to plants through their improved uptake and translocation by water. The increase in CGR was the result of greater LAD produced by persistent LAI from the availability of high soil-moisture content for a long period of crop growth. Prolonged LAD enabled the plants to intercept solar radiation over a longer period of time thus increased NAR. The plateau in CGR could be due to decreased NAR and increased respiration rate, and over shading of leaves by flowers that cut down the interception of solar radiation by leaves. Once it was recognized that respiration rates of shaded leaves were lower than those of fully illuminated leaves, plateau responses were accepted as reasonable (Gifford & Jenkins, 1982). However, they suggested that although individual leaf rate of respiration may decrease as biomass increases with increasing LAI, therefore, CGR should decrease above some optimum LAI. The increase in CGR for a short period of time before maturity could therefore be due to the rapid growth of pod (pod + seed) fraction.

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