Physiological constraints to productivity in Indian mustard (*B. juncea* L. Czern & Coss.)

M. L. Chhabra, B. K. Sinha, Dhiraj Singh, Kamal Dhawan, Rajesh Sharma

Department of Plant Breeding (Oilseeds section), Chaudhary Charan Singh, Haryana Agricultural University, Hisar-125 004 (India)
Email: drmlchhabra@hau.ernet.in

Abstract

Poor harvest index of rapeseed and mustard crop is one of the physiological constraint to productivity. The present paper focuses on the causes of poor partitioning of assimilates. Yield *per se* is complex character governed by many physiological attributes, viz: rate of photosynthesis, rate & magnitude of translocation from source to sink and the sink strength. Photosynthetic rate of leaves of *B. juncea, B. napus, and B. campestris* was nearly equal, but higher than that of *B. tournifortii*. The photosynthetic rate of different species was in the decreasing order; B. *tournifortii, B. napus, B. campestris, B. juncea.* Species *B. tournifortii* though has maximum photosynthetic rate is very poor seed yielder. Photosynthetic rate of the leaves as well as the flower buds was higher in *B. napus*, but it is poor yielder in most of Indian climatic conditions. Photosynthetic rate at 30 days after sowing stage was in the order: Upper leaves, lower leaves and middle leaves. At 60 days, it was lesser than at 30 DAS stage. Plucking lower half leaves at 40 to 70 days after sowing showed a significant increase in seed yield. When lower, middle, or upper leaf was fed with $^{14}CO_2$, the maximum incorporation of radioactive ^{14}C was from middle leaves. Comprehensive studies on *B. juncea* suggest that: compared to existing sink size, the source size is surplus. To divert translocation of assimilates from "vegetative sinks" (roots and lower leaves) to the siliquae; the magnitude of translocation needs to be improved through increase in sink strength.

Key words: Rapeseed and Mustard, Productivity, Assimilate Partitioning, Source: Sink relationship, *Brassica*

Introduction

Rapeseed mustard is grown annually on about 25.50 million hectares globally, 20.90% of which is in India with 12.80% production. As per currently available data, the crop occupies an area of about 6 million hectares with an average 6 million tones production annually with an average productivity of 1000 Kg. /ha.(Kolte,2005). Yield *per se* is very complex character governed by many physiological attributes, viz: net photosynthetic rate, sink strength, rate and magnitude of translocation of assimilate from source to sink. The objective of the present paper is to study photosynthetic rate, source sink manipulation, and translocation pattern in *Brassicas*.

Materials and methods

The present paper is grouped into following heads:

(1) Photosynthetic rate studies (2) Source sink manipulation studies (3) ^{14}C Translocation pattern studies

1. Photosynthetic rate studies: Photosynthetic rate studies were done by examining ^{14}C -incorporation /unit time/g dry weight of the tissue using assimilation tubes.

a) Comparative photosynthetic rate of leaves and flower buds of four Brassica species: Photosynthetic rate of leaves and flower buds of four Brassica species viz: *B. juncea* (var. RH-30), B. campestris (var. BSH-1), B. tournifortii (local), and *B. napus* (var.Tower), 60 days after sowing was studied.

b) Comparative photosynthetic rate of various green components of ***B. juncea:*** Photosynthetic rate of various green components viz: lower leaves, middle leaves, upper leaves, flower buds, pedicels, siliqua wall and seeds of *B. juncea* was examined at 30 and 60 days after sowing.

2. Source-Sink manipulation studies: Lower half leaves were plucked at 25, 40, 55, 70, 85,and 100 days after sowing and its impact was seen on seed yield and its components characters.

3. ^{14}C Translocation studies: ^{14}C was infiltrated to lower, middle or upper leaf of the plant and translocation pattern of radioactive sugars was examined in various plant components.

Results and discussion

(1)Photosynthetic rate studies:

a) Comparative photosynthetic rate of leaves and flower buds of four Brassica species:

i) **Leaves**: Photosynthetic rate of leaves of *B. juncea* var. RH-30; *B. campestris* var. BSH-1 and *B. napus* var. Tower, was nearly equal, but higher than that of *B. tournifortii* Var. local (Fig. 1).

ii) **Flower buds**: Photosynthetic rate of flower buds on dry weight basis was higher than leaves in all species except *B. juncea*. The photosynthetic rate of the different species was in the following decreasing order; *B. tournifortii* and *B. napus, B. campestris, B. juncea*. The photosynthetic rate of the flowering buds of *B. campestris* is about two-folds higher while that of *B. tournifortii and B. napus* was about four-folds higher than that of *B. juncea* (Fig. 1).

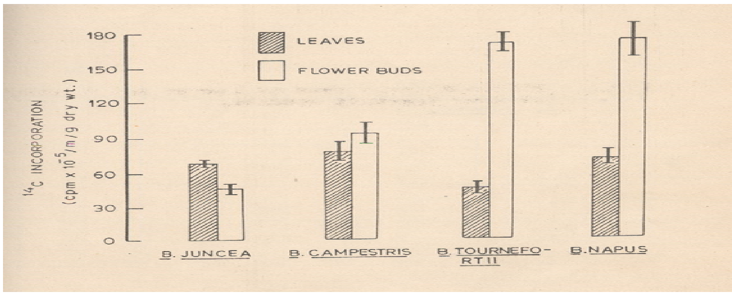

Fig. 1. Photosynthetic rate of leaves and flower buds of different *Brassica* species.

Data reveal that seed yield in *Brassica* is not associated with the photosynthetic rate of leaves. For example, *B. juncea* though highest seed yielder, its leaves are in no way photosynthetically superior to other species. Data further reveal that *B. juncea* though a high seed yielder is in no way superior to other species in terms of photosynthetic rate. However it cannot be inferred that photosynthesis has no association with seed yield. It can be reasonable to assume that in *Brassica*, there are some other physiological attributes other than rate of photosynthesis. Therefore, in order to achieve higher seed in existing genotypes of *Brassica,* the efforts should be concerted towards partitioning rather than increasing photosynthetic rate.

b) Comparative photosynthetic rate of various green components of *B. juncea*:

i) **At 30 days after sowing**: The photosynthetic rate of the leaves was in the following decreasing order: Upper leaves, middle leaves, and lower leaves. The upper leaves were 10% photosynthetically more active than the middle leaves, but, interestingly these were 3.1 folds more active than the lower leaves (Table 1). The stem is also photosynthetically active. Its photosynthetic rate was 30% higher than the lower leaves. The flower buds and pedicels were also photosynthetically equally active. Their activities were about 48% lesser than upper leaves, but were photosynthetically 59% more active than the lower leaves.

ii) **At 60 days after sowing**: The photosynthetic rate of the upper, middle, lower leaves was lesser than at 30 days after sowing. (Table1) by 38, 62, and 64% respectively. At stage-2, the flower buds were photosynthetically more active than even the upper leaves. The siliquae walls were also observed to be photosynthetically active, though their photosynthetic rate was about one-half than that of lower leaves and about one fourth of that of upper leaves. The green seeds *in vitro* were photosynthetically active but the siliqua wall was observed to be about 5.5 times photosynthetically more active than the seeds.

Overall, the photosynthetic rate of different components at stage-2 was in the order: flower buds, upper leaves = pedicels, middle leaves, lower leaves, stem, siliqua wall and the seeds respectively (Table 1).

Thirty days after sowing, the flower buds were photosynthetically less active than the upper and middle leaves. However, at 60 days after sowing, the flower buds were photosynthetically more active than leaves. Virtually there was no change in the photosynthetic rate of flower buds, but the photosynthetic rate of leaves was reduced with the advancement of age. This finding is in agreement with the observation of Chapman *et. al.* (1984).

Though the siliqua walls are photosynthetically lesser active than the leaves, this does not mean that they contribute less to seed yield. In one of the experiment removal of all leaves after 75 DAS does not cause any reduction in seed yield (data not presented). This observation reveals that at later stages of development, siliqua wall virtually contribute 100% to seed yield. The relatively higher contribution of siliqua wall to seed yield in spite of their being photosynthetically weaker than the leaves at the later stages of development is possibly because the seeds for their assimilatory requirement make a bias in favour of a closer source, i. e. the siliqua wall than the distantly located leaves. This proximity of the siliqua wall could not be overcome by the handicap of greater distance of the leaves. The photosynthetic nature of the siliqua wall in *Brassica* has earlier been reported (Hozyo *et. al.* 1972, Scott *et. al.*, 1973; Major, 1975; Major *et. al.*, 1978 and Mendham & Salisbury, 1995).

Table 1. Photosynthetic rate of green organs of *B. juncea* var. RH 30 plants at 30 and 60 DAS.

Plant part	Cpm x 10^{-3} /m/g dry weight Days after sowing	
	30 DAS	60 DAS
Lower leaves	2173+-82	1342+-196
Middle leaves	5897+-337	2211+-156
Upper leaves	6698+-206	2436+-205
Stem	2820+-189	913+-101
Flower buds	3673+-209	3827+-478
Pedicels	3461+-429	2713+-289
Siliqua wall	-	744+-289
Seeds	-	134+- 28
Siliquae	-	611+- 38

(2) Source: Sink manipulation studies:

a) Effect of plucking lower half leaves:

Plucking lower half leaves at 20, 40, 55 and 70 days after sowing caused a significant increase in seed yield, whereas, it remained unaffected by defoliating lower half leaves at 85 and 100 days after sowing (Table 2). A similar observation has earlier been observed by defoliating 25% leaves (Chhabra, 1986).

The number of siliquae/plant also increased significantly by defoliating lower half leaves at 25, 40, 55, and 70 days after sowing. The number of seeds/siliqua and 1000-seed weight remained unaffected by this defoliation treatment at all stages. On an overall, the increase in seed yield by this defoliation treatment was primarily due to an increase in number of siliqae/plant and this increase in number of siliquae/plant was primarily due to an increase in number of secondary and tertiary branches/plant. Question arises as to why there is an increase in seed yield on plucking lower half leaves. The possible explanation could be that the flower buds and siliqua wall being photosynthetically active contribute a significant amount of assimilates to the development of seeds. These lower half leaves which are photosynthetically very poor, when not contributing assimilates to reproductive sinks; rather act as "vegetative sinks" instead of serving as source of assimilates. Moreover, these leaves are source of many diseases as well. That is why their removal increases seed yield. This observation further suggests that breeders should not select genotypes having extra foliage. The concept of "vegetative sinks" in *Brassica* was first of all floated from this laboratory (Chhabra, 1986). This concept has further been confirmed based upon comprehensive source/ sink and translocation of assimilates studies (Chhabra, 1986). Thus it can be concluded that in *Brassica,* source is at least not a factor limiting the productivity in *Brassica*.

Table 2. Effect of defoliating lower half leaves on seed yield and yield components.

Defoliation (Days after sowing)	Seed yield (g)/Plant	No. of siliquae/plant	No. of seeds/siliqua	1000-seed weight (g)
Control	12.0	250.6	11.4	6.8
25	17.1	354.6	10.8	6.9
40	21.1	330.0	12.1	6.4
55	16.2	302.2	11.4	6.2
70	17.3	263..2	11.7	6.5
85	13.7	256.2	11.1	6.1
100	13.0	254.3	11.2	6.5
CD (5%)	4.0	50.5	NS	NS

Table 3. Translocation pattern of assimilates from lower, middle and upper leaves.

Plant part	Cpm X 10-3 /m/ g/ dry weight	Incorporation: per cent of total
	Lower leaf ^{14}C tagged	
Tagged leaf	68061+-18772	72.1
3 leaves above tagged leaf	4748+-363	5.0
3 top leaves	2062+-158	2.2
Inflorescence	19634+-5449	20.7
total	94505	-
	Middle leaf ^{14}C tagged	
Tagged leaf	23848+-1826	51.9
Lower 3 leaves	3944+-342	8.6
Upper 3 leaves	2859+-784	6.2
Inflorescence	15325+-2347	33.3
Total	45796	-
	Upper leaf ^{14}C tagged	
Tagged leaf	103429+-10632	69.3
3 leaves below tagged leaf	11187+-2006	7.5
3 lower most leaves	3731+-371	2.5
Inflorescence	30749+-1913	20.7
Total	149096	-

On an overall, following strategies should be adopted to increase seed yield in *Brassica*:

I) Select genotypes, which have moderate foliage and high harvest index. This is evident from the fact that past genotypes having excessive foliage are no more in existence now.

II) The role of photosynthesis of leaves should be given secondary importance. Efforts should be done to increase partitioning of assimilates through hormonal directed transport.

(3) ^{14}C Translocation pattern studies: Twenty hours after feeding lower leaf with $^{14}CO_2$ 20.7% of the radioactive counts were translocated to the inflorescence, 7.2% to 3- leaves above fed leaf and 3- top leaves. 72.1% assimilates remained un-translocated in fed leaf. This suggests that lower leaves are photosynthetically not very active. Feeding middle leaf resulted in translocation of higher percentage (33.3%) of assimilates to the inflorescence compared to 20.7% when lower leaf was fed. On an overall, the translocation of assimilates was maximum from middle leaf. Lower and upper leaves contributed lesser assimilates to the reproductive sinks. The possible explanation is that that upper leaves are too young and need a significant

proportion of food for their own growth and development, hence only little amount of assimilates from upper leaf is translocated to inflorescence (Chhabra *et. al.* 1999). Translocation of assimilates from lower leaves is also too less, because lower leaves being old leaves, too need a large proportion of assimilates for their own survival and hence only little proportion is left for translocation to inflorescence. On an overall, these lower leaves do not contribute towards the development of the plant and rather act as "Vegetative Sinks". Their removal instead of reducing seed yield increases seed yield.

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