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PHYSIOLOGICAL APPROACHES TO IMPROVING HARVEST INDEX AND PRODUCTIVITY IN SUNFLOWER

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SUMMARY

Factors associated with variation in harvest index and approaches to improve harvest index (HI) and productivity in sunflower are discussed in this article. In recent years, higher productivity in sunflower has been achieved mainly through increased crop growth rates. Besides, an improvement in harvest index also has contributed for improved productivity to a certain extent.

In our study we observed that medium duration types (100 to 110 days) had high HI compared with early or long-duration varieties and we also attempted to understand the ways and means to improve HI in sunflower types with varied duration.

Genotypes which had low partitioning of dry matter to stem plus thalamus had high HI. Genotypes which accumulated high biomass during post flowering stages of development also showed high HI and seed yield. In a few genotypes remobilization of photosynthates from vegetative plant parts to the seed resulted in high HI and seed yield. Among the sink characters, the number of seed per head, test weight and seed density (weight/volume) also contributed to achieving high HI values. Identification and selection of genotypes based on these criteria will increase the production further.

Since large amount of biomass is still locked up in the vegetative plant parts, any practice to manipulate the mobilization of photosynthates from vegetative parts to head also improves HI and thus seed yield. In our experiment, we observed that foliar application of boron nutrient and application of growth regulators to the head improved the translocation of photosynthates to the head and thus increased the HI and seed yield.

Key words: sunflower, harvest index, dry matter partitioning

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the major edible oilseed crops of India after groundnut and rape seed-mustard accounting for nearly 6.5% of the total oilseed production of the country (Anonymous, 1994). It is grown extensively in peninsular India primarily as a rainfed crop during monsoon season and to a certain extent in the post rainy season. In fact over the years, the crop has been replacing many of the traditionally grown crops such as sorghum, Bengal gram etc., With the emphasis on attaining self-sufficiency in oilseed production, there has been a national effort in encouraging its cultivation. However, one of the major deterrents in its adoption has been the poor productivity of the crop compared with other oilseed crops such as groundnut.

Several studies have addressed the issue of low productivity in sunflower and attempts have been made to develop varieties / hybrids with wide adaptability to biotic and abiotic stresses. However, an important approach to identify the factors limiting the productivity lies in understanding the physiology of the plant and the possible constraints that limit seed yield.

The possible paths among the factors contributing to productivity of any crop can be represented as depicted in Figure 1. Under adequate input conditions, the production is primarily determined by the average canopy cover (LAI), mean assimilation rate (NAR) and crop growth duration. The translocation of carbohydrates into economic parts is in turn dependent upon the efficiency of partitioning/harvest index (HI) of the plant.

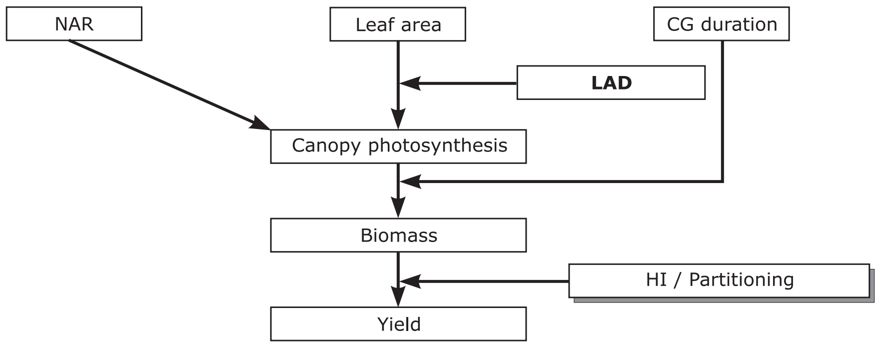

Figure 1: Schematic representation showing the possible factors contributing to productivity

Previous studies conducted at our laboratory showed that the low productivity is primarily due to poor canopy cover (LAI) in sunflower (Nanja Reddy *et al.*, 1994; Uma Shaanker *et al.*, 1994). Net assimilation rate (NAR) was generally high and not a major limitation to biomass productivity (Connor and Sadrass, 1992; Sheshsayee, 1992). The NAR in sunflower is equal to or sometimes higher than a few of the C_4 species (Nanja Reddy *et al.*, 1995a).

Despite such a high NAR in sunflower, the total biomass accumulated over the crop growth period is considerably less compared with many other crops of similar duration (Uma Shaanker, 1987; Nanja Reddy *et al.*, 1995). This is because of poor LAI values in sunflower. It has been argued that substantial improvement in the productivity could be obtained through improving the photosynthetic area. Several approaches including genetic and agronomic have also been proposed (Shivaram, 1986; Nanja Reddy *et al.*, 1994, 1995).

In this paper, we discuss the role of the partitioning efficiency or harvest index (HI) as yet another factor influencing the total economic productivity of sunflower. Basically we have shown the relationship of HI with seed yield across genotypes of sunflower and then we explored the patterns of variation in HI and analyzed in detail the factors associated with increase in HI. Finally, we offered possible approaches to improve HI in an effort to increase the seed yield in sunflower.

RESULTS AND DISCUSSION

1. Patterns of variation in HI and its relationship to productivity

Translation of biomass to seed yield is the key factor for altering the productivity. In sunflower, the importance of HI towards productivity has been well documented (Nanja Reddy *et al.*, 1994, 1995). However, the extent of contribution of HI towards seed yield varies with season, environmental conditions and management practices during crop growth stage (Hegde, 1987; Shivaram, 1986; Nanja Reddy *et al.*, 1994, 1995). In one of our studies, among 49 genotypes including both old varieties and recent hybrids, the seed yield different to an extent of 103% and HI to an extent of 21% (Table 1) and total biomass to an extent of 69%. This suggests that, in sunflower, the yield improvement in the recent past is achieved primarily by increased biomass production and to certain extent by increased harvest index.

Table 1: Harvest index (HI) and total dry matter (TDM) in sunflower plants different for seed yield ± 5.0 g

Yield type	Seed yield (g/plant)	HI	TDM (g/plant)
High (n=22)	46.3	0.34	139.5
Low (n=27)	22.8	0.28	82.4
SD ±	5.0		
% increase in high yielder over low yielders	103.0	21.0	69.0

Table 2: Variation in harvest index of sunflower hybrids and varieties

	Hybrids (n=35)	Varieties (n=35)
Range	0.25 - 0.44	0.14 – 0.44
Mean ± SD	0.35 ± 0.05	0.29 ± 0.06

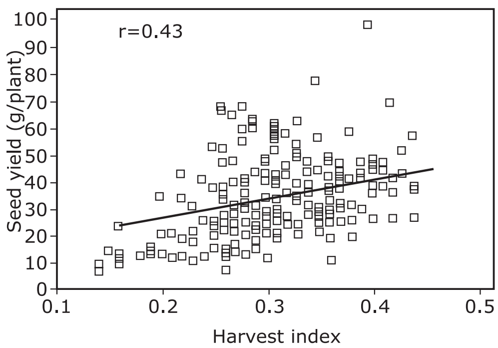

Figure 2: Relationship between harvest index and seed yield in sunflower

In the present analysis with 206 genotypes (which includes populations, varieties, introductions and hybrids), the HI was positively associated with productivity (Figure 2: r=0.43, P<0.05). Variation in HI with 206 genotypes followed a normal distribution pattern and showed a wide range from 0.14 to 0.44 (Figure 3a). HI varies with season, population density (Hegde, 1987; Shivaram, 1986) and duration of genotypes. Summer season showed more HI compared with rainy season crop (Krishne Gowda, 1984; Nanja Reddy *et al.*, 1994). Mid-duration group of 101-110 days showed higher HI compared with short- or long-duration group (Figure 3b). Hybrids showed higher HI compared with inbreds (Table 2). Those variations in HI suggests that potential exists to improve HI and thus the seed yield of sunflower. Therefore, the varieties or hybrids of mid-duration types may be generated for high HI from the germ plasm.

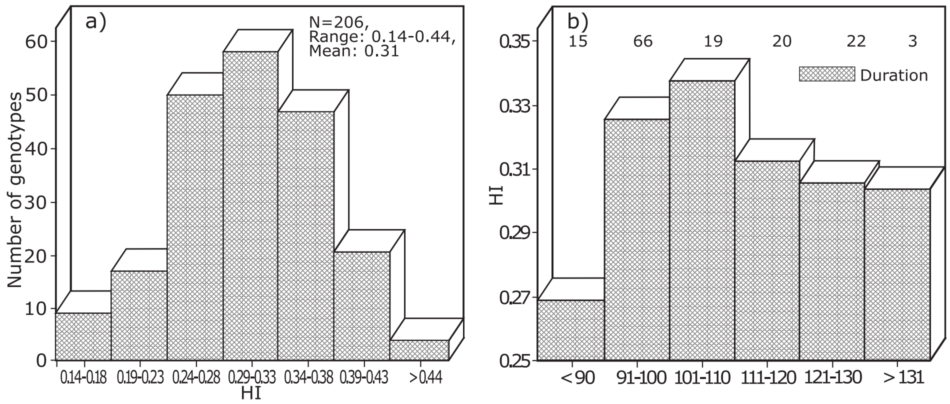

Figure 3: Frequency distribution of HI in sunflower varieties (a) and across the duration groups (b)

2.Factors associated with increased HI

Based on several studies in our laboratory and earlier reports (Krishne Gowda, 1984; Naik, 1991; Hegde, 1987, Shivaram, 1986; Nanja Reddy *et al.*, 1994, 1995; Uma Shaanker *et al.*, 1994), we propose here a scheme for improving HI (Figure 4). The possible approaches are (a) reducing thalamus weight, (b) increasing post-anthesis biomass production and (c) increased partitioning of biomass to sink by improving sink characters.

Figure 5a shows that high yielders maintain high HI mainly by decreased partitioning of biomass to leaf, stem and thalamus. A negative significant relationship was observed between percent biomass allocation to stem plus thalamus and grain yield (r=-0.82, P<0.05) or HI (r=-0.75, P<0.05) (Figure 5b). This indicates that the partitioning of dry matter to stem and thalamus should be less to achieve high HI. However, the exact percent of accumulation of biomass in stem plus thalamus must be optimized, since thalamus weight is also important as a space for putting a large seed number and stem to hold the weight of the seed-bearing head.

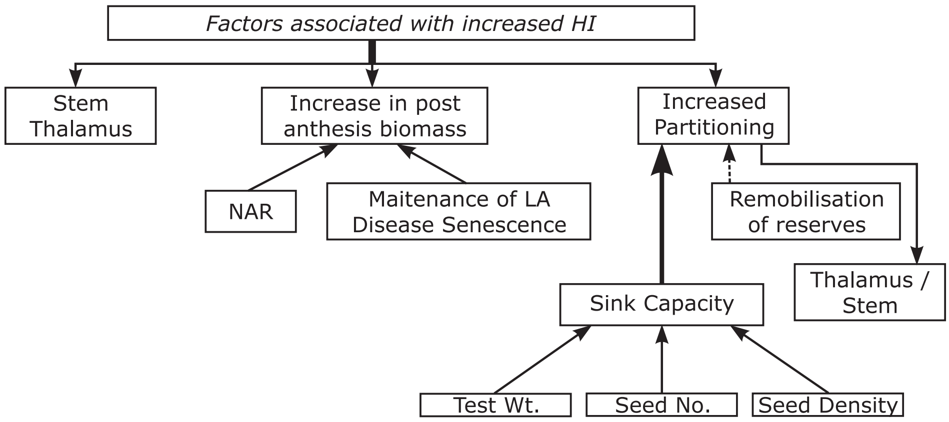

Figure 4: Schematic representation showing the factors associated with an increased harvest index in sunflower

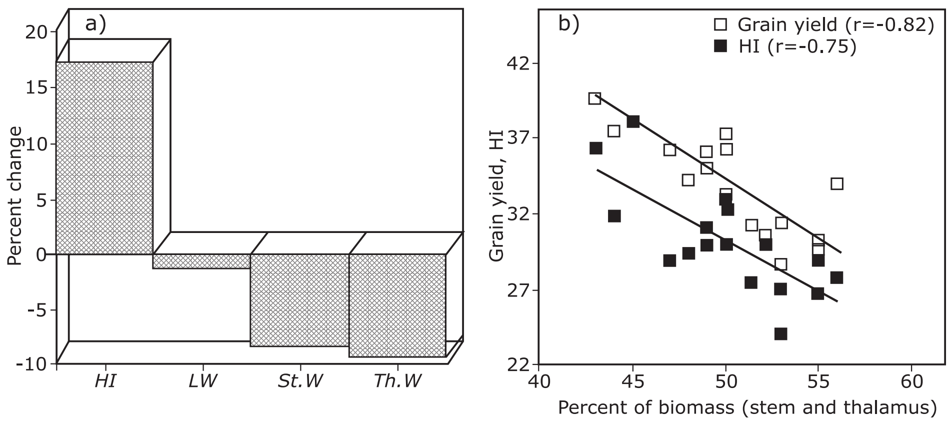

Figure 5: Comparative partition showing the factors associated with an increased harvest index in sunflower

Another feature which determines the HI and productivity is the extent of post-anthesis biomass production. In sunflower, by anthesis stage, vegetative growth and reproductive structures development is almost completed. Therefore, the dry matter produced after anthesis is probably allocated more towards seed filling process. Thus selecting a genotype for high biomass production during post-anthesis would result in high HI and seed yields. In our experiments with seven genotypes, we observed a highly positive significant relationship between seed yield and post-anthesis dry matter ($r=0.75$, $P<0.05$) and the TDM with LAD ($r=0.49$, $P<0.05$) (Figures 6a and 6b). This indicates that the maintenance of high LAD during post-anthesis period either by decreased leaf senescence or by reduced leaf disease incidence. We emphasize that the maintenance of high post-anthesis LAD is an important pre-requisite to achieve high productivity in sunflower.

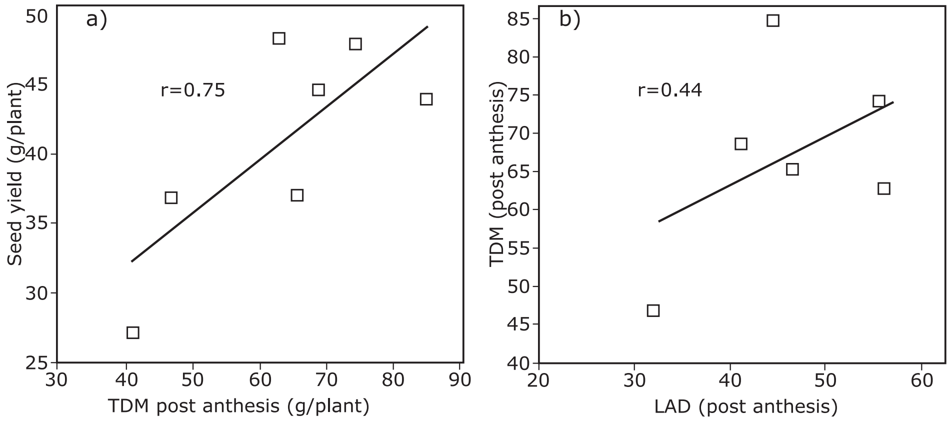

Figure 6: Relationship between post-anthesis biomass production and seed yield (a) and post-anthesis LAD and post-anthesis dry matter production in sunflower (b) (Adopted from Siddaraju, 1986)

Yet another parameter which influences HI is partitioning efficiency which is dependent on remobilization of reserved carbohydrates from stem and thalamus and the increased sink capacity. It was found that the genotypes with high biomass at anthesis are shown to have high remobilization upto an extent of 47% and thus high HI and seed yields (Table 3).

Table 3: Effect of dry matter accumulation at anthesis on harvest index and seed yields in sunflower

Genotype	DM type	TDM at anthesis	HI	Seed yield	Pre-anthesis contribution
Acc 1253	High	415	0.28	139	47.5
Acc 121	High	399	0.25	116	47.4
Acc 1633	Low	267	0.21	93	0.0
Acc 1250	Low	201	0.20	67	0.0
CD (P<0.05)		54	0.02	13	

TDM and seed yield are expressed in g per five plants and pre-anthesis contribution in percentage

This was substantiated by Hall *et al.* (1989) wherein they reported that the genotypes vary in remobilization of stored carbohydrates to seed yield to an extent of 27% based on the degree of translocation. Further, by increasing sink capacity through increased test weight or by seed number per head or by seed density individually or collectively can increase the HI and productivity (Table 4).

These results suggest that for high HI and seed yield, a genotype should be selected for high biomass accumulation by the time of anthesis with least senescence of leaves during post-anthesis period by having more translocation of metabolites towards seed filling than allocation towards stem or thalamus.

Table 4: Effect of seed number per head and test weight on HI and seed yield and sunflower

Genotype	Seed no./head	Test weight (g/100 seeds)	HI	Seed yield (g m^{-2})
KBSH 1	1423	6.33	0.33	403
Acc 1266	1222	7.97	0.32	453
Acc 697-1	928	6.10	0.27	245
Acc 1872	722	6.18	0.26	210
CD (P<0.05)	240	1.85	0.04	103

3. Possible approaches to improve harvest index

In many genotypes large amounts of metabolites are locked up in vegetative organs like stem, leaf and thalamus. Any approach which promote remobilization of photosynthates from vegetative to reproductive organs influences HI and thus productivity.

Soil application of boron (2 kg/ha) at ray floret stage increased the HI to an extent of 29% and the seed yield by 53% (Table 5). Boron is known to play an important role in translocation of sugars.

Table 5: Effect of boron application on harvest index and seed yield of sunflower (hybrid KBSH 1)

Treatment	Seed yield (q/ha)	HI
Control	10.0	0.31
Borax (2 kg/ha)		
At button stage	14.3	0.39
At ray floret stage	15.3	0.40
CD (P<0.05)	1.2	0.02

(Adopted from Naik, 1991)

Table 6: Effect of TIBA and NAA application on sink characters and seed yield of sunflower (cv. Morden) at constant source size

Treatment	Head diameter (cm)	Filled seed no./head	Weight of filled seed (g)	1000-seed weight (g)	Seed yield (kg ha^{-1})
Control	15.0	624	31.2	49.9	968
TIBA (240 ppm)	16.8	701	48.8	60.7	1246
TIBA (240 ppm) + NAA (50 ppm)	18.3	764	52.6	68.8	1295
CD (P<0.05)	2.1	84	6.3	3.3	44

(Addopted form Prasad *et al*., 1978)
TIBA: tri-iodobenzoic acid
NAA: napthalene acetic acid

Application of TIBA alone or TIBA with NAA have also been found to increase seed yield by 29 and 34% respectively (Table 6). Exogenous application of growth regulators to the developing head was shown to increase the transport of photosynthate from leaf to the developing head (Prasad *et al.*, 1978). Tri-iodobenzoic acid, an inhibitor of polar transport of auxins, increased the sink capacity of the head and thus movement of metabolites from vegetative organs to the head (Prasad *et al.*, 1978). These results indicate that the translocation of metabolites from vegetative organs to seed is also a limitation for achieving high HI and any attempt to improve transport of photosynthates from source to sink improves HI and seed yield.

CONCLUSIONS

Genotypic variability of HI exists, thus HI can be used as a selection criterion to improve sunflower productivity.

Maintenance of greater LAD during post-anthesis period leads to enhanced dry matter production, HI and seed yield.

Leaf area duration can be maintained by identifying low leaf senescence types and disease tolerant types particularly for rust and *Alternaria* which generally prevail during end season of the crop (especially during rainy season crop).

Sink capacity seems to be a limitation for achieving high HI, therefore by applying boron or TIBA with NAA, sunk capacity and thus HI can be improved leading to increased seed yield.

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ACERCAMIENTO FISIOLÓGICO AL MEJORAMIENTO DEL ÍNDICE DE COSECHA Y AL RENDIMIENTO EN GIRASOL

RESUMEN

En este trabajo se han considerado los factores vinculados con la variación del índice de cosecha y los acercamientos del mejoramiento del índice de cosecha (IC) y del rendimiento en girasol. En los últimos años, mayor productividad de girasol se logra en mayor grado mediante el aumento de tasa de crecimiento de plantación. Aparte de ello, a la productividad aumentada, en cierta medida también ha contribuido el mejoramiento del índice de cosecha.

En nuestro trabajo se ha determinado que los genotipos de una duración media de vegetación (100-110 días) tienen alto IC en comparación con las variedades tempranas o tardías, y también se ha hecho un intento de comprender los modos y medios para el mejoramiento del CI del girasol con diferentes duraciones de vegetación.

Los genotipos con diminuta distribución de la materia seca en el tallo con el ovario tenían el IC alto. Los genotipos que habían acumulado una cantidad de biomasa grande en las fases después de floración, tenían también alto el IC y el rendimiento de semilla. En varios genotipos, la removilización de fotosintatos de las partes vegetativas de planta en la semilla, resultó con el alto IC y rendimiento de semilla. De las propiedades vinculadas con la adopción de la materia seca, al logro de altos valores de IC también han contribuido el número de semilla por cabeza, la masa hectolítrica y la densidad de semilla (masa / volumen). La identificación y la selección de genotipos, basada en estos criterios, llevará a la continuación de incremento de producción.

Teniendo en cuenta que una cantidad grande de biomasa todavía queda presa en las partes vegetativas de la planta, cada medida con la cual se manipula con la movilización de fotosintatos de las partes de la planta vegetativas en la cabeza, también aumentarán el IC, y por lo tanto, el rendimiento de la semilla. En nuestro ensayo se ha notado que la aplicación foliar de boro, tanto como la aplicación de reguladores de crecimiento en la cabeza de girasol mejora la translocación de fotosintatos en la cabeza de la planta, y de tal manera aumenta el IC y el rendimiento de la semilla.

APPROCHE PHYSIOLOGIQUE DE L'AMÉLIORATION DE L'INDEX DE MOISSON ET DE PRODUCTIVITÉ DU TOURNESOL

RÉSUMÉ

Dans cet article, les facteurs liés à la variation de l'index de moisson et les démarches en vue d'améliorer l'index de moisson (IM) et la productivité du tournesol sont étudiés. Ces dernières années on arrive à une plus grande productivité du tournesol surtout par l'augmentation du taux de croissance des

plantes. De plus l'amélioration de l'index de moisson a contribué dans une certaine mesure à une augmentation de la productivité.

Notre travail a établi que les génotypes de végétation à durée moyenne (100-110 jours) avaient un haut IM en comparaison avec les sortes précoces ou tardives et nous avons tenté de comprendre les manières et les moyens d'améliorer le IM des tournesols ayant différentes durées de végétation.

Les génotypes à faible distribution de matière sèche dans la tige avec pistil avaient un grand IM. Les génotypes qui accumulaient une grande quantité de biomasse dans les phases suivant la floraison avaient un grand IM et un grand rendement de graines. Dans quelques génotypes la remobilisation des photosyntates des parties végétatives des plantes dans les graines a résulté en un IM élevé et un grand rendement des graines. Parmi les caractéristiques liées à l'appropriation de matière sèche, le nombre de graines par tête, la masse par hectolitre et la densité des graines (masse/volume) ont aussi contribué à ce qu'une grande valeur de IM soit atteinte. L'identification et la sélection des génotypes basées sur ces critères conduiront à une augmentation ultérieure de la production.

Étant donné qu'une grande quantité de la biomasse est toujours confinée dans les parties végétatives de la plante, toute mesure permettant la manipulation par mobilisation de photosyntates des parties végétatives de la plante dans la tête augmentera le IM et le rendement des graines. Notre expérience a montré que l'application de bore aux feuilles et l'application de régulateurs de croissance à la tête du tournesol amélioraient la translocation des photosyntates à la tête de la plante et augmentait ainsi le IM et le rendement des graines.