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Accumulation and translocation of dry matter and nitrogen in different purple corn hybrids (*Zea mays* L.)

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In this study, five purple corn hybrids (ZS7615, ZF7139, FS7011, FG5701, 68G1) and one commercial grain hybrid ZD958 were studied to investigate the changes in accumulation, partitioning and translocation of dry matter and N. Results indicated that the total aboveground dry matter of all hybrids increased from anthesis to maturity. Conversely, the dry matter of vegetative organs significantly decreased. All hybrids exhibited an obvious trend of decrease in concentrations of N from seedling stage to maturity. However, N accumulations had reversely changes. Of all the purple corn hybrids, the hybrid 68G1 had a relatively higher grain yield, grain N and dry matter of husk and cob which had the highest anthocyanins. The harvest index and N harvest index of 68G1 were also higher than other purple corn hybrids. There was a significant correlation between grain yield and harvest index and grain N. The findings are helpful to make a nutrient regime recommendation for purple corn production. It also suggests a further genetic improvement for breeding new purple corn hybrid which had both higher grain yield and aboveground dry matter.

Key words: Purple corn, dry matter, nitrogen, partitioning, anthocyanins.

INTRODUCTION

Purple corn (Zea mays L.) has been recognized as a "black health food" by people, compared with other crops in our country. For centuries, purple corn had been cultivated in South America, mainly in Peru. Purple corn (*Zea mays* L.) as a pigmented variety of maize is being grown increasingly in the world, but there is a lack of information about nutrients limiting its biomass and grain yield.The grain of purple corn was a health food for people. While, the product of purple corn, the leaf, stem, husk and cob of purple corn contain rich anthocyanins including cyaniding-3-dimalonylylucoside, peonidin-3-glucoside, pelargonidin-3-glucoside, cyaniding-3-glucoside (Harborne and Self, 1997; Aoki et al., 2002; Pascual et al., 2002). Hence, interest in purple corn as a source of anthocyanins, a natural colorant used for coloring beverages, candies had increased over the years.

Although the aboveground dry matter and N accumulation, partitioning and translocation have been well documented in sweet sorghum (Zhao, 2009), wheat (Dordas, 2009), cotton (Mohamed et al., 2010), and normal maize (Moll et al*.,* 1994; Pan et al., 1995), little is known about the aboveground dry matter and N accumulation, partitioning and translocation of purple corn. The dynamics of N accumulation and partitioning were important to form a high biomass and grain yield, and were closely related to N cycling in the soil-plant-processing system (Epstein and Bloom, 2005). N partitioning and utilization can partly control plant productivity. The dry matter and N partitioning parameters in maize were affected by nitrogen. Of the partitioning parameters assessed, N utilization showed the highest association with corn yield (Hu et al., 2010; Guillermo et al*.,* 2011). Pan et al. (1995) reported that dry matter partitioning of maize was positively related to N accumulation and inversely related to N mobilization. Most of the N accumulated in grain was derived by translocation of N accumulated pre-anthesis in vegetative organs during the grain filling period (Cartelle et al., 2006). Different genetic maize may had different effects on N accumulation, as well as influenced by available

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Abbreviations: CDMG, Contribution of pre-anthesis dry matter to grain; **CNG,** contribution of pre-anthesis N to grain N.

Table 1. Source and types of six maize single-cross hybrids.

No.	Hybrid	Source	Type of hybrid	Characteristics of parental type
1	ZS7615	SCISAU	Purple corn hybrid	♀: only the ear is purple, normal grain type; ♂: the whole plant is purple, normal grain type
2	ZF7139	SCISAU	Purple corn hybrid	♀: only the ear is purple, normal grain type; ♂: the whole plant is purple, waxy grain type
3	FS7011	SCISAU	Purple corn hybrid	♀: the whole plant is purple, waxy grain type; ♂: the whole plant is purple, normal grain type
4	FG5701	SCISAU	Purple corn hybrid	♀: the whole plant is purple, waxy grain type; ♂: the whole plant is purple, normal grain type
5	68G1	SCISAU	Varicolored corn hybrid	♀: the whole plant is green, normal grain type; ♂: the whole plant is purple, normal grain type
6	ZD958	HAAS	Yellow grain hybrid	♀: the whole plant is green, normal grain type; ♂: the whole plant is green, normal grain type

SCISAU, Specialty Corn Institute of Shenyang Agricultural University; HAAS, Henan Agricultural Academy Sciences; ♀: female parent; ♂: male parent.

water (Clarke et al., 1990), the supply of nitrogen (Cox et al., 1985a; Papakosta and Gagianas, 1991) and other properties of genotype during the pre-anthesis and post-anthesis period. Moll et al. (1994) tested nine genetic maize hybrids and reported continuous absorption of N after anthesis resulting in increasing yield which was accompanied by a parallel increase in total dry matter and N accumulation.

For most field crops, the residues may be incorporated into soils and compensate N losses after the grains or/and tubers were harvested. It is different that the entire aboveground organs of purple corn, as raw materials of anthocyanins extraction, are considered to be harvested for anthocyanins extraction in industry production. The understanding of N dynamic of the purple corn will be helpful to maintain soil N balance via fertilization or/ and genetic improvement. It is also important for anthocyanins extraction to reduce its feedstock cost. Information of dry matter, N accumulation and partitioning of purple corn could serve for optimizing fertilization application for a high biomass and grain yield.

The objective of this study was to determine the differences in accumulation, partitioning and translocation of dry matter and N of different genetic hybrids. And data were collected for breeding purple corn hybrids with higher biomass and grain yield in the future.

MATERIALS AND METHODS

Plant materials

Five purple corn hybrids including ZS7615, ZF7139, FS7011, FG5701, 68G1 and one commercial normal grain hybrid ZD958 were tested in the present study. The sources and types of six maize single-cross hybrids are listed in Table 1.

Study site and experimental design

This field study was conducted in 2009-2010 at the experimental station (41°49′N, 123°34′E) of Shenyang Agricultural University in Shenyang, China. The site has a continental monsoon type climate falling mostly in June, July and August. The data of temperature, rainfall and sunshine hours during the study period were collected from a meteorological station located close to the experiment site and are presented in Table 2. Corn hybrids were sown on sandy loam soil. The main chemical properties of the soils are presented in Table 3.

The experiment was arranged in a randomized complete block design with three replications. Each plot consisted 8 rows, 8 m in length and spaced 0.6 m between rows. Corn hybrids were sown with a sowing machine in May 12, 2009 and May 14, 2010 at a target population of 52500 plants ha^{-1}. Basal fertilizer 75 kg N ha^{-1} as urea, 60 kg P_2O_5 ha^{-1} as diammonium phosphate and 75 kg K_2O ha^{-1} as potassium sulfate were applied just before sowing. 150 kg N ha^{-1} as urea was applied at trumpet stage. Three seeds were planted in a hole. The distance between the plants was 31.7 cm. Thinning was done to leave one plant per hole after 15 days from seedling emergence. The crop field was kept free of weeds by hand when it is necessary.

Sampling and measurements

Five aboveground maize hybrid plants were taken on the date of seedling (25 days after planting, DAP), elongation (38 DAP), trumpet (54 DAP), anthesis (73 DAP), grain filling (93 DAP) and maturity stages (125 DAP) from each plot. The sample of plants was not separated and a mixed plant sample of the whole plant was made at seedling stage, elongation and pre-tasselling stages, while

Table 2. Mean temperature, rainfall and sunshine hours at the experimental station of Shenyang Agricultural University during study period.

Month	Mean temperature (oC)			Mean rainfall (mm)			Mean sunshine hours (h)		
	Long-term average	2009	2010	Long-term average	2009	2010	Long-term average	2009	2010
Mar-May	9.5	10.2	7.1	32.2	47.6	64.6	238.0	241.8	208.2
Jun-Aug	24.7	22.4	23.4	134.7	94.9	197.0	221.3	210.7	194.3
Sept-Nov	7.9	7.8	8.9	40.8	33.0	50.4	66.9	71.7	75.2

Table 3. Chemical properties of the soil (0-20cm depth) at the experiment site.

Year	Total N ($g\ kg^{-1}$)	Available N ($mg\ g^{-1}$)	Total P ($g\ kg^{-1}$)	Olsen P ($mg\ g^{-1}$)	Total K ($g\ kg^{-1}$)	Available K ($mg\ g^{-1}$)	Organic matter ($g\ kg^{-1}$)
2009	2.0	103.0	0.9	27.3	24.5	128.7	21.5
2010	2.2	106.0	0.9	31.8	24.1	158.4	20.9

the sample of plants was separated into two components (leaf + sheath + stem + tassel, un-polinated ear) at anthesis, three components (leaf + sheath + stem + tassel, husk + cob, grain) at grain filling stage and maturity. After the components were separated, all the fresh parts of different components were weighed up, cut into pieces, mixed and sub-samples were taken for fresh weight. Then these fresh sub-samples were oven-dried at 85℃ for 72 h for estimation of aboveground dry matter by sample proportion. The dried sub-samples were ground with a mill to pass through a 0.5 mm mesh for N analysis by Kjedahl method (Nelso and Sommers, 1980). The N content of the plant parts is presented as N concentration ($g\ kg^{-1}$).

Calculation and statistical analysis

The parameters related to dry matter and N accumulation, partitioning and translocating of maize hybrid plants discussed in this paper were calculated according to Papakosta and Gagianas (1991); Cox et al., (1985a,b,1986) and Papakosta (1994):

1. Dry matter translocation (DMT) (tha^{-1}) = dry matter at anthesis – dry matter at maturity (all vegetative parts except grain);
2. Dry matter translocation efficiency (DMTE) (%) = dry matter translocation / dry matter at anthesis × 100;
3. Contribution of pre-anthesis dry matter to grain (CDMG) (%) = dry matter translocation / grain yield at maturity × 100;
4. Harvest index (HI) = grain yield/dry matter at maturity;
5. N translocation (NT) ($kgha^{-1}$) = N accumulation at anthesis – N accumulation at maturity (all vegetative parts except grain);
6. N translocation efficiency (NTE) (%) = N translocation / N accumulation at anthesis × 100;
7. Contribution of pre-anthesis N to grain (CNG) (%) = N translocation / grain N accumulation at maturity × 100
8. N harvest index (NHI) = grain N at maturity / total N accumulation at maturity.

ANOVA was conducted using SAS (SAS Institute, 9.1.3 ed, 2008). The statistical significance of the differences were determined by the least significant difference at the P<0.05 level.

RESULTS

Dry matter accumulation and partitioning at anthesis and maturity

Dry matter accumulation and partitioning in different organs among different genetic maize hybrids used in this study were different at anthesis and maturity stages (Table 4). At anthesis stage, the dry matter of vegetative organs (leaf + sheath + stem + tassel) (8.18-11.20 t ha^{-1}) were higher than the un-pollinated ear dry matter (1.07-3.35 t ha^{-1}). Generally, the purple corn hybrids except ZS7615 had a higher dry matter and the commercial hybrid ZD958 had a lower amount of total aboveground dry matter at anthesis. The dry matter accumulation of un-pollinated ear and vegetative organs (leaf + sheath + stem + tassel) of different hybrids had significantly differences ($P<0.05$), but there was no significant difference of the total aboveground dry matter at anthesis stage. The vegetative organs (leaf + sheath + stem + tassel) dry matter (7.53-10.45 t ha^{-1}) was related to the grain (6.04-9.12 t ha^{-1}) at maturity.

The dry matter translocation of different genetic maize hybrids ranged from -1.42-2.38 t ha^{-1} (The data were added in Table 4) during anthesis and maturity stages. The contribution of pre-anthesis dry matter to grain (CDMG) of purple corn hybrids ZF7139 and FS7011 could not be determined. The two-year average CDMG differed among the four hybrids (68G1, FG5701, ZS7615, ZD958) which ranged from 1.34-36.63%. While, the dry matter translocation efficiency (DMTE) were 13.43, 16.31, 6.76 and 1.2%, respectively. It should be noted that there were obviously genetic differences among the hybrids for the contribution of pre-anthesis photosynthesis to grain

Table 4. Changes in aboveground dry matter and its partitioning of different maize hybrids at anthesis and maturity stages (averaged across two years).

Hybrid	Anthesis			Maturity				DMT	HI	CDMG(%)
	Vegetative organ	Unpolinated ear	$Total_a$	Vegetative organ	Husk+ cob	Grain	$Total_m$			
ZS7615	8.18^b	2.94^{ab}	11.12^a	7.65^c	2.75ab	6.4^b	16.80^b	$0.72a^{bc}$	0.38^b	12.19b
ZF7139	10.68^{ab}	1.79^c	12.47^a	10.45^a	3.44a	6.04b	19.93^a	-1.42^c	0.30^c	–
FS7011	10.516^{ab}	1.52^c	12.03^a	9.62^{ab}	2.85ab	6.14b	$18.61a^b$	$-0.44b^c$	0.33^c	–
FG5701	11.205^a	1.07^c	12.27^a	8.07^c	1.82b	6.27b	16.16^b	2.38^a	0.39^b	36.63^a
68G1	$8.80a^b$	3.35^a	12.15^a	7.53^c	2.99a	7.09b	17.60^{ab}	1.63^{ab}	0.40^b	23.02^b
ZD958	$8.92a^b$	2.53^b	11.45^a	8.22^{bc}	3.12a	9.12a	20.46^a	0.12^{bc}	0.45^a	1.34^c

Vegetative organs include leaf, sheath, stem and tassel; $Total_a$, total dry matter at anthesis; $Total_m$, total dry matter at maturity; -, data is not available because the value is negative. The different small letters indicate significant differences at P<0.05 level.

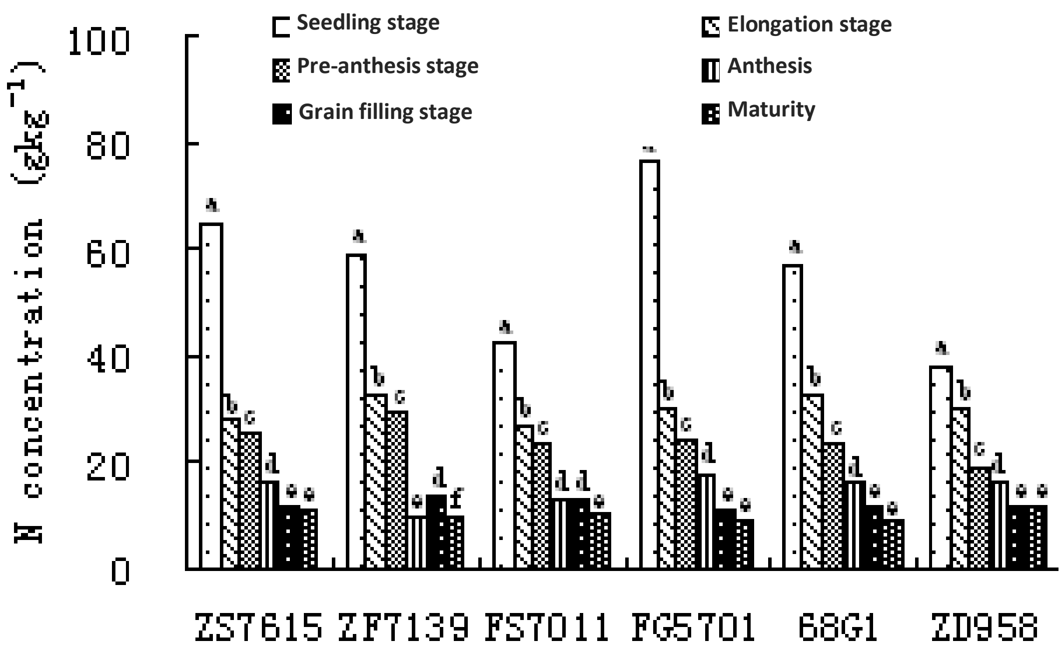

Figure 1. N concentration in different maize hybrids during different growing stages.

yield. A reduction in dry matter of vegetative organs after anthesis was recorded in all of the hybrids. It means that the dry matter losses of vegetative after anthesis may be translocated for grain filling. There were significant differences in grain yield between the purple corn hybrids and commercial normal grain maize hybrid.

In this experiment the harvest index of five purple corn hybrids was significantly reduced compared with commercial hybrid ZD958. Whereas, the total dry weight at anthesis and maturity stages were significantly increased compared with commercial hybrid. This is because the proportion of change in the total aboveground dry matter and grain yield was constant. Compared to other purple corn hybrid, hybrids FG5701 and ZF7139 had higher values than the others at anthesis and maturity stages that contributed with reducing grain weight compared with commercial hybrid ZD958. The dry matter parameters of hybrid 68G1 had higher values than other purple corn hybrids.

N concentration, accumulation and partitioning

Different genetic maize hybrids studied in the experiment exhibited an obvious trend of decrease in N concentrations in aboveground plants from seedling to maturity stages (Figure 1). N concentrations that ranged between 37.88 to 76.32 gkg^{-1} at seedling stage were significantly

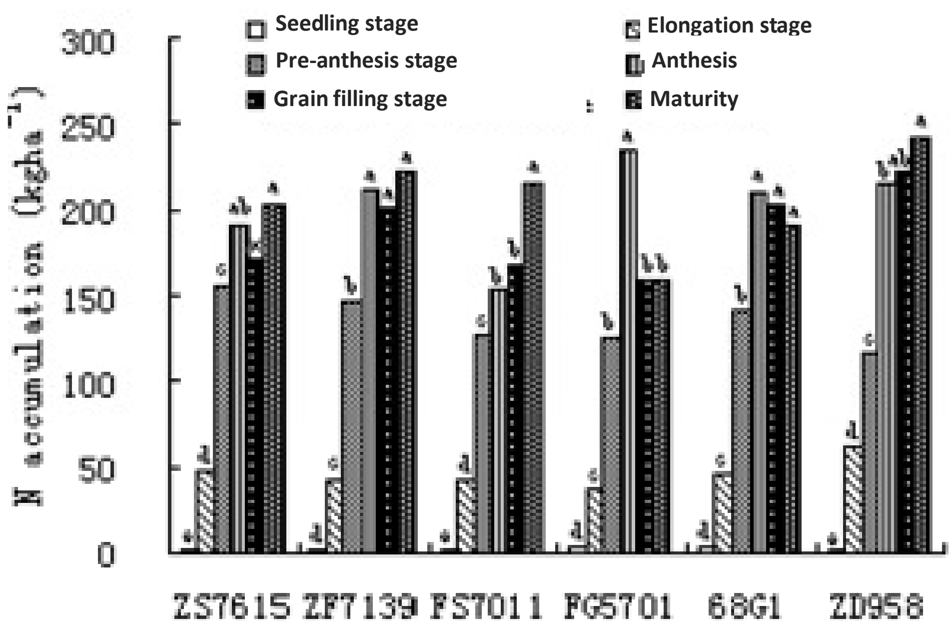

Figure 2. N accumulations in different maize hybrids during different growing stages.

Table 5. Changes in N accumulation and partitioning in different maize hybrids at anthesis and maturity stages (averaged across two years).

Hybrid	Anthesis			Maturity				NHI	CNG(%)
	Vegetative organ	Unpolinated ear	$Total_a$	Vegetative organ	Husk+cob	Grain	$Total_m$		
ZS7615	149.24^{b}	40.29^{ab}	189.53^{ab}	79.01^{cd}	16.93^{a}	108.40^{b}	204.35^{ab}	0.53^{b}	88.21^{bc}
ZF7139	184.37a^{b}	28.04^{c}	212.40^{a}	105.95^{a}	16.35^{ab}	100.15^{bc}	222.46^{ab}	0.45^{c}	89.33^{bc}
FS7011	138.53^{b}	16.08^{d}	154.61^{b}	98.02a^{b}	17.53^{a}	99.82^{bc}	215.37^{ab}	0.46^{c}	40.30^{c}
FG5701	225.19^{a}	12.80^{d}	237.99^{a}	64.00^{d}	11.39^{b}	84.76^{c}	160.14^{c}	0.53^{b}	190.63^{a}
68G1	164.61^{b}	45.36^{a}	209.97^{a}	62.24^{d}	15.39^{ab}	113.15^{b}	190.78^{bc}	0.59^{a}	117.43^{b}
ZD958	183.06^{ab}	32.76b^{c}	215.81^{a}	85.47b^{c}	14.28^{ab}	141.61^{a}	241.37^{a}	0.59^{a}	82.01^{bc}

Vegetative organs include leaf, sheath, stem and tassel; $Total_a$, Total N at anthesis; $Total_m$, Total N at maturity. The different small letters indicate significant differences at P<0.05 level.

(1.3 to 2.5 times) (p<0.01) higher than at elongation stage on the whole plant biomass. Although the N concentrations of different genetic maize hybrids at seedling stage were much higher than the other stages (Figure 1). It was obvious that the N accumulation significantly (P<0.01) increased from seedling stage to elongation for all maize hybrids compared with commercial hybrid ZD958 that accumulated N significantly until maturity stage (Figure 2). This is due to more biomass accumulation from seedling stage (0.0336 to 0.0386 t ha^{-1}) to elongation stage (1.218 to 1.832 t ha^{-1}) (Data not shown).

All the hybrids with different genetic background exhibited increases in N accumulation from seedling to anthesis stage. The N accumulations in aboveground maize hybrid at maturity were 160.14 to 241.37 kg ha^{-1}(Table 5). The hybrids 68G1, ZS7615, ZF7139, and FG5701 exhibited a little decrease in N accumulation from anthesis to grain filling stage. While FS7011 and ZD958 showed continuous increase from anthesis to maturity stages. The purple corn hybrids 68G1 and FG5701 which had the same male parent exhibited the highest N accumulation at anthesis. Although, there was a slight reduction in the N concentration in grains of purple corn from grain filling stage (16.1 to 22.8 g kg^{-1}) (Data not shown) to maturity (13.5 to 16.9 g kg^{-1}), the N accumulation in maize grains increased significantly (P<0.05) during the same period because of a large increase of grain yield.

The concentrations of N in grain were 1.2 to 1.8 times higher than (P<0.01) in vegetative organs (leaf + sheath + stem + tassel) on grain filling stage for all maize hybrids (Data not shown). However, because most of the biomass was found in vegetative, N accumulation in grains was 1.61 to3.52 times lower (P<0.01). N harvest

Table 6. Correlation coefficient between the aboveground dry matter and N parameters.

Coefficient	PODM	DMM	DMT	DMTE	HI	GY	PAN	PON	NM	NT	NTE	NHI	GN
PODM	1												
DMM	0.96**	1											
DMT	-0.75	-0.79*	1										
DMTE	-0.72	-0.79*	0.99***	1									
HI	0.09	-0.07	0.59	0.62	1								
GY	0.62	0.51	0.05	0.09	0.83*	1							
PAN	-0.17	-0.10	0.46	0.41	0.41	0.28	1						
PON	0.70	0.62	-0.77*	-0.72	-0.26	0.14	-0.82*	1					
NM	0.98***	0.91*	-0.81*	-0.77	-0.01	0.51	-0.34	0.82	1				
NT	-0.43	-0.4	0.76*	0.73	0.57	0.25	0.92**	-0.91	-0.59	1			
NTE	-0.43	-0.44	0.79*	0.79*	0.64	0.30	0.86**	0.86	-0.56	0.98**	1		
NHI	0.001	-0.13	0.63	0.68	0.94**	0.74	0.45	-0.33	-0.09	0.64	0.74	1	
GN	0.77*	0.63	-0.21	-0.14	0.64	0.92*	0.03	0.43	0.73	-0.04	0.06	0.61	1

DMM, dry matter at maturity; DMT, dry matter translocation; DMTE, dry matter translocation efficiency; GN: Grain N; GY, grain yield; HI, Harvest index; NHI, N harvest index; NM, N at maturity; NT, N translocation; NTE, N translocation efficiency; PAN, pre-anthesis N; PODM, post-anthesis dry matter; PON, post-anthesis N. *, Significant at 0.05 probability level; **, Significant at 0.01probability level; ***, Significant at 0.001 probability level.

index represents the ability of translocation of N from vegetative organs to grain. Among the five purple corn hybrids, the 68G1 had the highest N harvest index, while ZF7139 had the lowest. It should be noted that the N harvest index of purple corn was lower than normal grain hybrid ZD958. The contribution of pre-anthesis N to grain N (CNG) of different maize hybrids ranged from 82.01 to 190.63% and the average of CNG of purple corn hybrids were also higher than normal grain hybrid ZD958.

Correlation coefficients between dry matter and N parameters characters at corn growth stages

In all different genetic maize hybrids, the dry matter translocation and N translocation were different. The dry matter translocation had significant correlation with N translocation (0.76) and N translocation efficiency (0.79) (Table 6). The significantly correlation coefficient between pre-anthesis N and N translocation was 0.92. Therefore, the value of pre-anthesis N was useful for predicting the performance of mobilized N. Generally, correlation between N translocation and pre-anthesis dry matter was not significant. The correlation between N translocation and grain yield was positive but insignificant.

N translocation efficiency was an important index for breeding new hybrid. Hybrid 68G1 had relatively higher N translocation efficiency (63.01%) among the purple corn hybrids. N translocation efficiency was in significant positive correlation with pre-anthesis N and was negatively correlated with post-anthesis dry matter, dry matter and N accumulation at maturity. Grain N was not significantly correlated with any of the indexes list in Table 6 except post-anthesis dry matter and grain yield. N harvest index was in significant positive correlation with harvest index. The relationships with other indexes were inconsistent. Harvest index and N harvest index had similar trends as the same as grain yield.

DISCUSSION

The results of this study indicated that, the value of dry matter at pre-anthesis was much higher than at post-anthesis stage. Although there were purple corn hybrids ZF7139 and FS7011 with negative dry matter translocation, there was also a possibility of pre-anthesis dry matter contributed to grain because of continued photosynthesis after anthesis also having an effect on grain filling. Bidinger et al. (1977) reported the contribution of pre-anthesis dry matter to grain yield ranged 12 to 27%, even though there were increases in the weight of the vegetative parts after anthesis. Austin et al. (1977) thought only 73% of vegetative losses were used for grain filling. The respiratory losses (Rawson and Evans, 1971) and losses of dead leaves (Bidinger et al., 1977) may account for the rest of losses. Maize hybrids with higher contribution of pre-anthesis dry matter to grain tended to have lower yields. In this study, the correlation coefficient between dry matter translocation and grain yield was only 0.05, which means that the dry matter translocation had no important meaning for grain yield prediction. Although the grain yield of ZD958 was much higher than purple corn hybrid, partially because ZD958 had a much higher post-anthesis dry matter than purple corn hybrid. Maize hybrids with higher contribution of pre-anthesis dry matter to grain tended to have lower yields. Blum et al. (1994) reported that there was no negative correlation between CDMG and grain yield. It is necessary to select genotypes both had higher CDMG and more efficient post-anthesis assimilation in the future study.

All maize hybrids used in this study exhibited an obvious trend of decrease in concentrations of N in aboveground plants from seedling stage to grain maturity. N concentration decreased from anthesis to maturity in vegetative organs indicating remobilization of N to other parts of the plants such as seed. These agree with the results from other plants, such as winter wheat (Dordas, 2009). Conversely, the increase in N accumulation was found because of increases of biomass accumulation that return to crop growth. It is expected and in agreement with the findings for all annual crops (Barker and Pilbeam, 2007). The pre-anthesis contribution of biomass to N concentration was less important than N accumulation. Whereas N accumulation was affected by water (Clarke et al., 1990), nitrate fertilizer (Cox et al., 1985a), genotype and growth conditions. The results of this study also showed that the N concentration of ZD958 at maturity was lower than purple corn except FG5701.

N translocation efficiency represents the translocation ability of N from vegetative organs to grain. This effect appeared in that the N concentrations of vegetative organs of maize hybrid at maturity that was lower than at grain filling stage. The findings are in agreement with a previous study on sorghum (Lu et al., 1999). N translocation efficiencies of maize hybrids ranged from 18%-49.7%.Hybrid ZD958 had the lowest N translocation efficiency, indicating lower N remobilization than purple corn in vegetative organs.

The grain of purple corn can be used as food and the aboveground dry matter especially the cob and husk can be used as raw materials for anthocyanins extraction. Hence, selection of a purple corn hybrid that gives higher grain yield and biomass with minimum input is a main future research objective. It is worthwhile to consider the grain yield and biomass to breeding new purple corn hybrid in the future.

Conclusion

This field study demonstrated that nitrogen affected dry matter and N translocation in different organs of plant between anthesis and maturity. The total aboveground dry matter and N accumulation of different maize hybrids at maturity were different. The purple corn hybrid which had a normal inbred as female parent had higher grain yield and dry matter of husk and cob than other purple corn hybrids. As the raw material of anthocyanins extraction, the husk and cob were the main organs containing rich anthocyanins. This study also showed a decrease in N concentrations in maize hybrid above-ground plants from seedling stage to maturity, change N accumulation was the reverse from seedling stage to anthesis. The concentrations of N in purple corn hybrids were higher than commercial normal maize hybrid at different stages. Among the five purple corn hybrids, the hybrid with normal corn female parent had higher values of dry matter and N parameters. Thus breeders can use the highest dry matter content hybrid in improvement corn program. In order to improve the yield and aboveground dry matter of purple corn, breeders can follow similar methods in breeding program for purple corn and normal grain corn. In addition, suggesting a genetic improvement optimizing N use efficiency of purple corn hybrid, the findings of this study are also helpful to make N fertilization recommendation for purple corn anthocyanins extraction production in China.

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