Evaluation of phenotypic variation in a worldwide germplasm collection of safflower grown under organic farming conditions in South West Germany

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Introduction

In Central Europe, rape and sunflower represent the major oil crops in conventional farming (Schmidt et al., 2003). However, for organic production these two crops have many limitations. Organic rape requires high amount of nitrogen and is attacked by several pests which often results in yields less than 1t per ha (Leifert, 2001). Sunflower performs well only under a warmer climate and needs high amount of fertilization to give an optimum yield (Putnam et al., 1993). Safflower (*Carthamus tinctorius* L.) now cultivated mainly for its seed, which is used as edible oil and as birdseed (Mündel and Huang, 2003). Germplasm collections continue to play a vital role in providing the genetic resources needed for improving safflower (Johnson et al., 2001). This study was designed to quantify the level of phenotypic variation among accessions, find adapted accessions for organic farming in Central Europe, and to select accessions to serve as the genetic base for an organic breeding program.

Material and Methods

A worldwide germplasm collection constituted 467 accessions of *Carthamus tinctorius* L. and one accession of *Carthamus lanatus* L. was under evaluation for phenotypic traits during the seasons of 2004 and 2005. The accessions were evaluated for the following agromorphological traits: seedlings/m², plant height in cm, days to 5% and 95% flowering (when 5% and 95% of plants in each row were flowered), days to maturity, yield/m², yield/plant, thousand kernel weight (TKW), plants/row, seeds/plant and lodging. Rust (*Puccinia carthami*), Alternaria leaf spot (ALS; *Alternaria carthami*), and head rot (*Botrytis cinerea* or *Sclerotinia sclerotiorum*) diseases were rated in per cent. The experiment was carried out at Kleinhohenheim organic farm (SW-Germany, lat: 48°45'N long: 9°11'E, alt: 435 m). The average temperature and sum of precipitation during the growing period were 15.7 °C and 309 mm in 2004 and 16 °C and 486 mm in 2005, respectively. In a simple lattice design with two replicates, 25 seeds from each accession were drilled in 120-cm-long rows spaced 75 cm apart. Combined ANOVA was run and coefficients of variation (C.V.), broad sense heritability (h²B) and phenotypic coefficients of correlation between traits were estimated using PLABSTAT (Utz, 2002).

Results and Discussion

The combined analysis of variance results revealed a highly significant variation among evaluated accessions and years for all investigated traits except lodging (Table-1). Accession x year interaction was significant for all traits with the exception of plant height, days to beginning and end of flowering, and days to maturity. Coefficients of variation for accessions ranged from 2.6 to 80.5% with the highest C.V. was recorded for yiled/m², yield/plant and seeds/plant. Environmental (years) coefficients of variation ranged from 1.6 to 85.5%. The rated diseases, head rot, ALS and rust, Lodging, and oil content were most affected by environment as indicated by the highest C.Vs (Table-1). High heritabilities were observed for most studied traits. The degree of heritability varied between 10% for lodging to86% for plant height.

Table-1: Combined analysis of variance, coefficient of variation and heritability for 468 accessions grown under organic farming system in season 2004 and 2005.

Trait	Source of variance	df	Mean	C.V.%	F-Value	Heritability h^2B
	Year (Y)	1		3.2	8.8**	
Seedlings/Row	Genotype (G)	467	11.9	31.8	4.3**	77
	Y x G	464		10.5	1.2**	
	Year	1		31.5	2338.9**	
Rust %	Genotype	467	46.6	12.7	2.6**	62
	Y x G	464		5.6	1.2*	
	Year	1		85.5	2007.4**	
Head rot %	Genotype	467	46.6	15.9	1.3**	23
	Y x G	464		37.1	5.2**	
	Year	1		45.1	2395.5**	
Leaf spot %	Genotype	467	34.1	19.8	3.0**	66
	Y x G	464		9.5	1.3**	
	Year	1		78.5	860.9**	
Lodging (1-9)	Genotype	467	2.4	13.3	1.1	10
	Y x G	464		43.3	2.3**	
	Year	1		6.3	454.1**	
Height (cm)	Genotype	465	104.1	11.0	6.9**	86
	Y x G	463		0.0	0.9	
	Year	1		3.1	309.7**	
Begin of flowering (days)	Genotype	465	99.3	7.2	3.2**	69
	Y x G	464		4.1	0.75	
	Year	1		1.9	236.2**	
End of flowering (days)	Genotype	465	112.7	4.0	5.8**	83
	Y x G	463		0.0	0.7	
	Year	1		1.6	306.7**	
Days to Maturity	Genotype	465	136.7	2.6	4.6**	78
	Y x G	463		0.0	0.4	
	Year	1		3.5	10.1**	
Plants/Row	Genotype	464	11.8	30.5	4.0**	75
	Y x G	463		11.0	1.2**	
	Year	1		20.7	557.8**	
TKW (g)	Genotype	464	23.5	22.8	3.9**	74
	Y x G	450		13.8	2.2**	
	Year	1		10.2	14.3**	
Yield/m² (g)	Genotype	465	93.9	80.5	4.7**	78
	Y x G	459		60.0	2.0**	
	Year	1		18.3	49.7**	
Yield/plant (g)	Genotype	465	6.8	64.3	3.6**	72
	Y x G	457		39.1	1.9**	
	Year	1		12.1	21.6**	
Seeds/plant	Genotype	463	258.7	57.6	3.0**	67
	Y x G	449		50.0	4.1**	
	Year	1		34.9	1079.9**	
Oil content %†	Genotype	199	9.7	15.1	3.0**	67
	Y x G	199		12.3	3.0**	

*'** are significant at 5% and 1%, respectively. C.V. is coefficient of variation. † Combined analysis of variance was run for subset of 200 selected accessions.

It is clear that accessions harbored considerable variability for most studied traits. The accessions completed flowering in 97 to 129 days from sowing and their plants matured in 124 to 149 days. These results could explain the effect of low temperatures recorded during the growing seasons in prolonging the rosette stage and hence delaying maturity. The seed yield among the accessions ranged from 2 to 476 g m^{-2} and from 0.1 to 33 g $plant^{-1}$. There were 66 accessions, most of them are originated in Europe, in which the seed yield/m² was significantly higher than the mean yield of all accessions (92.9 g m^{-2}). Regarding oil content, in average all accessions showed very low oil content compared to existing cultivars of other oil crops. The Canadian genotype PI-572475 (Saffire) produced the highest oil content (22.8%), but it was not significantly different from 146 accessions. In this collection considerable variation among accessions for the rated diseases was observed. Out of 468 accessions, 77% in 2005 had head rot susceptibility ratings of more than 50%, whereas in 2004 only 4 accessions had head rot rating of more than 50%. The wild accession (BS-52826) showed the highest resistance for head rot, rust, and ALS diseases. Among *C. tinctorius* L. germplasm, thirty two accessions, most of them originated in Europe, revealed relatively low susceptibility to head rot (less than 20%). For leaf spot disease, thirteen accessions had low susceptibility ratings. So these accessions could be of valuable genetic resource for further safflower breeding.

Although significant phenotypic coefficients of correlation were observed between several traits, the r-values were generally less than 0.50, indicating that the relationships between traits often did not explain a large portion in total variability (Data not presented). Plant height had a positive correlation with days to 95% flowering (0.67**), and days to maturity (0.54**). There was slight but significant association between yield/m² and days to maturity (0.41**). Yield/m² positively correlated with seeds/plants (0.083**) and TKW (0.64**). Significant positive correlation (0.53**) between TKW and seeds/plant was obtained. A strong desirable positive correlation (0.71**) between yield/m² and oil content was observed. These relationships with the observed high heritability along with high C.Vs. demonstrated that screening criteria could be based on yield/m², seeds/plant, and TKW.

Conclusion

The results indicated that sufficient variability exists in most of the traits studied. It was possible to identify accessions, most of them originating in Europe that appeared tolerant to head rot and alternaria leaf spot, the most serious diseases under temperate climate and organic conditions. It may be possible that safflower can compete with the existing oil crops by breeding for higher oil content in the future.

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