

**ENHANCING FOOD SECURITY IN ARID AREAS OF PAKISTAN THROUGH  
NEWLY DEVELOPED DROUGHT TOLERANT AND SHORT DURATION MUSTARD  
(*Brassica juncea* L.) CANOLA**

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Food security is the crucial global issue, especially in developing countries like Pakistan. Since edible oil is an essential food item, its persistent paucity in the country and huge import for meeting domestic requirements, has attained it second largest import item after petroleum products. The aim of present study is qualitative and quantitative evaluation of newly developed short duration and drought tolerant canola quality *Brassica juncea* lines ZBJ-06012 and ZBJ-08051 to overcome the *unfavorable edible oil situation in the country*. Thirteen lines were evaluated in randomized complete block design (RCBD) for seed yield, oil quality, maturity period and drought tolerance under different agro-climatic zones both in irrigated and arid areas across the Punjab province at eight locations in Micro Yield Trials during Rabi season 2012-13 and 2013-14. Presently, grown non-canola mustard varieties Khanpur Raya and Anmol Raya were used as check varieties. *Brassica napus* cultivars Punjab canola and Faisal canola were also included in the trials for comparison study of mustard and rapeseed genotypes. Data for all traits under observation was analyzed through Principle Component Analysis (PCA) to evaluate the best performing lines in irrigated as well as in rain fed areas. Principal Component Analysis showed first 2 PCs having Eigen value >1 explaining 76.4% and 72% of the total variation at irrigated areas and rain fed areas respectively. The mean seed yield was also compared by Least Significant Difference (LSD) test to study the significance at 5% probability level. Canola quality *B. juncea* lines ZBJ-06012 and ZBJ-08051 have shown good adaptability, early maturity, non-

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shattering, disease and drought tolerance traits with high yield potential in comparison with presently grown *Brassica napus* cultivars “Punjab Canola” and “Faisal Canola”. Due to these prominent features, these lines have a great scope for motivating farmers to grow canola quality *B. juncea* when compared with *B. napus* and non-canola *B. juncea*. Future challenges demand further development of high yielding, short duration and aphid tolerant mustard cultivars having high oil content and canola quality. There is a great potential of exploiting genetic variability in the existing *B. juncea* material to achieve the aforesaid goals by using conventional plant breeding techniques.

*Key words:* *B. juncea*, drought tolerance, food security, genetic variability, short duration

## INTRODUCTION

*Brassica juncea* L. belongs to the family Brassicaceae. It is a major oilseed crop of the subcontinent. It is rich source of protein with well-proportioned amino gram (AKMAL, *et al.*, 2011). *B. juncea* is more adaptable oilseed crop than *Brassica napus* in arid areas. It has more vigorous seedling growth, faster ground covering ability, better tolerance to heat and drought along with better resistance to the blackleg fungus, *Leptosphaeri amaculans* than *B. napus* (BURTON, *et al.*, 1999; WOODS, *et al.*, 1991). *B. juncea* silique are non-shattering and seeds potentially contain a higher percentage of oil and protein because of thinner seed coat. The potential benefits of developing canola quality *B. juncea* are recognized by a number of northern hemisphere countries (BURTON *et al.*, 1999).

All over the world, mustard is used for its appetizing flavor and preservative value. Its seeds are used mostly for moderating food. Oil is consumed for both edible and non-edible purpose (RAKOW and RANEY, 2003). Palm oil promotes heart disease by raising blood cholesterol (TEMME *et al.*, 1996). Lower content of erucic acid are helpful in cardiac problems. Recently, *B. juncea* has been explored for its biodiesel potential (JHAM *et al.*, 2009).

Pakistan is facing severe scarcity of edible oil due to increase in demand and production gap, thus edible oil production does not match with growing demand of population (FAZAL, *et al.*, 2015). Consequently, a huge volume of foreign exchange is spent every year on its import to gratify the requirement (HASAN, *et al.*, 2015). During the year 2013-14, the local production of 0.573 million tonnes against the 3.20 million tonnes total need of edible oil and imported 2.627 million tonnes of edible oil worth US\$ 2.50 billion. The major share in imported edible oil is of palm oil which is low in quality and causes serious health problems (Govt. of Pakistan, 2014-15).

In rapeseed and mustard seeds per plant is the trait which mainly contributes in seed yield improvement because of high broad sense heritability, highly significant positive correlation and maximum positive direct effects on seed yield (HASAN, *et al.*, 2014). Drought negatively affects the chlorophyll content in plants. Drought decrease crop production and vegetation leading to increase the toxic substances that are harmful for livestock. Cultivars with high tolerance against abiotic stresses especially drought and salinity is the need of hour throughout the world (DENBY and GEHRING, 2005; MUSTAFA, *et al.*, 2015). ZHANG *et al.*, (2014) stated that drought severely effects crop growth & development and ultimately cause yield loss. *Brassica* crops have a large share in total oilseed production therefore; it is time need to develop drought tolerant cultivars to ensure food security under adverse climatic change.

The present study summarizes that *B. juncea* has potential as an oil crop for arid areas of Pakistan. The Oilseeds Research Institute, Faisalabad is the only research institute in Pakistan working on the development of canola varieties in summer mustard. The breeding program is aiming to develop canola quality (double low) *B. juncea* cultivars which are high yielding, early maturing, bold seeded and disease tolerant with good drought tolerant traits. The key objective is to select canola quality mustard genotypes which are earlier than the newly developed *B. napus* cultivars “Punjab canola” and “Faisal canola” along with comparable or enhanced yields.

#### MATERIALS AND METHODS

The promising Canola quality *B. juncea* lines ZBJ-06012 and ZBJ-08051 have been developed through hybridization using pedigree method at research area of Oilseeds Research Institute, Faisalabad, Pakistan. Homozygous progenies of these lines from F6 were bulked in 2005-06 for yield evaluation. Canola quality *B. juncea* lines ZBJ-06012 and ZBJ-08051 with other seven advance lines were evaluated under different agro-climatic zones both in irrigated (Faisalabad, Bahawalpur, Mianwali, Khanpur) and arid areas (Chakwal, Bhakkar, Karor, Fateh Jang) across the Punjab province at eight locations in Micro Yield Trials during Rabi season 2012-13 and 2013-14. Presently, grown non-canola mustard varieties Khanpur Raya and Raya Anmol were used as check varieties. *Brassica napus* cultivars Punjab canola and Faisal canola were also included in the trials for comparison study of mustard and rapeseed genotypes. The wide range of environments, particularly low rainfall areas where different genotypes were sown in order to select lines with wider adaptation and also check the yield potential in these areas. The trials were sown following randomized complete block design (RCBD) with three replications. Each plot consisted of 5 meter long three rows for each entry. Seeds were planted with the help of a seed drill and the distance between rows was kept 45cm. At all locations standard agronomic and cultural practices recommended for rapeseed & mustard cultivations were applied to the experiments throughout the growing season. The data regarding seed yield and other agronomic & drought related traits were collected from trials sites in both the years. Nuclear Magnetic Resonance apparatus (MQA 7005 Oxford) were used to estimate the oil percentage while quality of oil (fatty acid profile & 00) was determined by Gas Chromatograph apparatus (Varian CP-3900) in Hi-Tech Oil Technology laboratory of Oilseeds Research Institute, Faisalabad, Pakistan.

#### *Statistical Analysis*

The data was subjected to Principal Component Analysis (Sneath and Sokal, 1973) using statistical software package Minitab 17. The first two principal components were plotted against each other to find out the patterns of variability among genotypes. The mean seed yield was also compared by Least Significant Difference (LSD) test to study the significance at 5% probability level by using Statistix 8.1. Data collected were subjected to analysis of variance (ANOVA) for RCBD experiment using the method described by STEEL and TORRIE (1980). The F-LSD procedure as described by OBI (2001) was used in separating the treatment means.

#### RESULTS AND DISCUSSION

Mean seed yield results with days to maturity of micro yield trials (2012-13 and 2013-14) conducted in irrigated areas (Faisalabad, Bahawalpur, Mianwali, Khanpur) and arid areas

(Chakwal, Bhakkar, Karor, Fateh Jang) across the Punjab province are presented in (Table 1) along with check (*B. juncea*) and comparison varieties (*B. napus*).

Table 1. Mean data of micro yield trials 2012-13 and 2013-14

Variety/line	Mean data from irrigated areas				Mean data from arid areas				Drought tolerance
	Seed Yield 2012-13 (kg $ha^{-2}$ )	Days to maturity 2012-13	Seed Yield 2013-14 (kg $ha^{-2}$ )	Days to maturity 2013-14	Seed Yield 2012-13 (kg $ha^{-2}$ )	Days to maturity 2012-13	Seed Yield 2013-14 (kg $ha^{-2}$ )	Days to maturity 2013-14	
Anmol									M
Raya (C)	1642	144	1854	148	1490	130	1399	131	
Khanpur									T
Raya (C)	1803	152	2435	155	1622	138	1592	141	
ZBJ-06012	2866	116	3163	118	2665	114	2752	113	T
ZBJ-08051	2748	120	3021	122	2654	117	2565	118	T
KJ-266	1996	134	1900	137	1620	126	1617	129	M
KJ-258	2203	151	2445	151	1904	133	1900	135	M
RBJ-08015	2268	144	2633	141	2188	139	2089	140	M
BRJ-09010	2309	146	2624	143	2159	140	2183	141	M
RBJ -10008									S
	1924	135	2470	140	1865	128	1657	130	
RBJ-10786	2468	146	2849	145	2294	138	2270	139	T
11CBJ-004	2659	153	2937	155	2438	146	2481	150	S
Punjab									S
Canola (C)	2734	154	2843	153	1644	147	1226	151	
Faisal									S
Canola (C)	2669	156	2976	154	1707	148	1772	157	
LSD 5%	372.051		455.368		462.497		437.291		

C = Check & Comparison varieties, T = Tolerant, M = Moderately tolerant, S = Susceptible

#### Performance of genotypes in irrigated areas

The bi-plot of irrigated areas presented in Fig. 1 showed the contribution of first two principle components explaining 76.40% of total variation. Across all four irrigated locations (Faisalabad, Bahawalpur, Mianwali, Khanpur) during 2012-13 and 2013-14, ZBJ-06012 and ZBJ-08051 showed low erucic acid, low glucosinolates, early maturing and drought tolerant and produced seed yield at par to *B. napus* canola cultivars Punjab canola and Faisal canola and gave higher yield than non-canola mustard cultivars. The oil content of these lines was also found at par to the *B. napus* cultivars. ZBJ-06012, ZBJ-08051, Punjab canola and Faisal canola showed significantly higher seed yield than the check varieties Khanpur Raya and Anmol Raya in irrigated areas of Punjab (Pakistan). Similar kind of results has been found in the studies of Mahmood *et al.*, 2017.

*Principal Component Analysis: (Irrigated)*

Eigen value	2.8056	1.0136	0.8230	0.2763	0.0815
Proportion	0.561	0.203	0.165	0.055	0.016
Cumulative	0.561	0.764	0.928	0.984	1.000

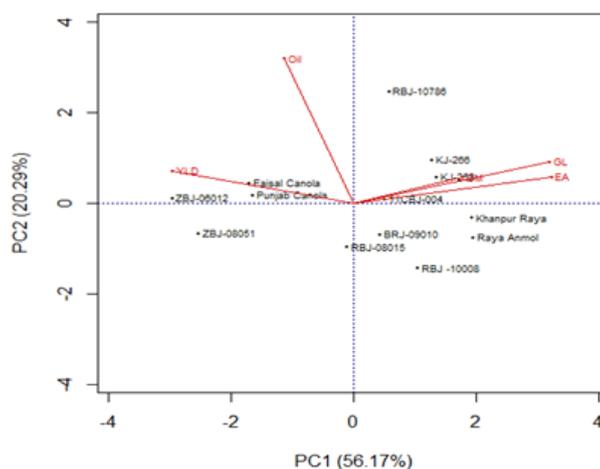


Fig. 1. Bi-plot of genotypes in irrigated areas

*Performance of genotypes in rain fed areas:*

The bi-plot of rain-fed areas presented in Fig. 2 showed the contribution of first two principle components explaining 76.40% of total variation. Across all four rain-fed locations (Chakwal, Bhakkar, Karor, Fateh Jang) during 2012-13 and 2013-14, ZBJ-06012 and ZBJ-08051 showed low erucic acid, low glucosinolates, early maturing and drought tolerant and produced highest seed yield in comparison with *B. napus* canola cultivars and non-canola mustard cultivars. *B. napus* cultivars, Faisal canola and Punjab canola showed highest oil content in rain-fed areas. The oil content of ZBJ-06012 and ZBJ-08051 was found at par to the *B. napus* cultivars. ZBJ-06012 and ZBJ-08051 showed significantly higher seed yield than the check varieties Khanpur Raya and Anmol Raya in rain-fed areas of Punjab (Pakistan). The promising lines ZBJ-06012 & ZBJ-08051 had very short maturity period and good seed yield when compared to non-canola mustard and *B. napus* cultivars. In arid areas of Punjab (Pakistan) mustard canola cultivars performed better and gave higher yield than *B. napus* cultivars i.e., Punjab canola and Faisal canola. Similar kind of findings has been found in the studies of Burton *et al.*, 1999.

*Principal Component Analysis: (Rain-fed)*

Eigen value	2.3318	1.2668	0.7701	0.5423	0.0890
Proportion	0.466	0.253	0.154	0.108	0.018
Cumulative	0.466	0.720	0.874	0.982	1.000

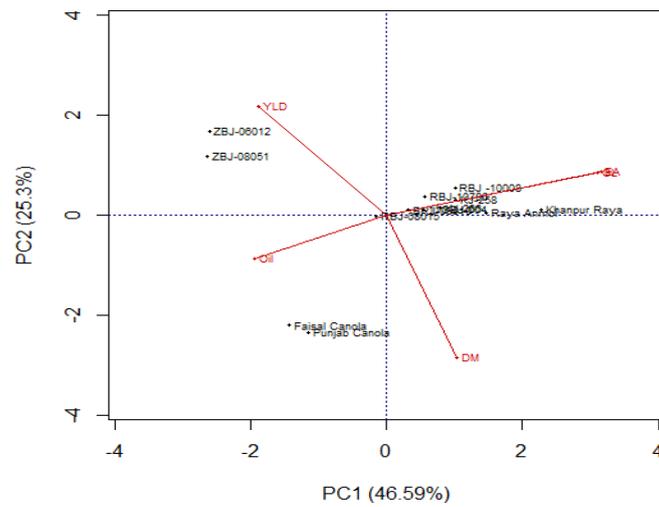


Fig. 2. Bi-plot of genotypes in rain fed areas

*Seed yield of genotypes at all locations:*

The bi-plot for seed yield at all eight locations presented in Fig. 3 showed the contribution of first two principle components explaining 96.7% of total variation. The bi-plot showed that ZBJ-06012 and ZBJ-0851 performed well and gave highest seed yield than *B. napus* canola cultivars and non-canola mustard cultivars across all eight locations.

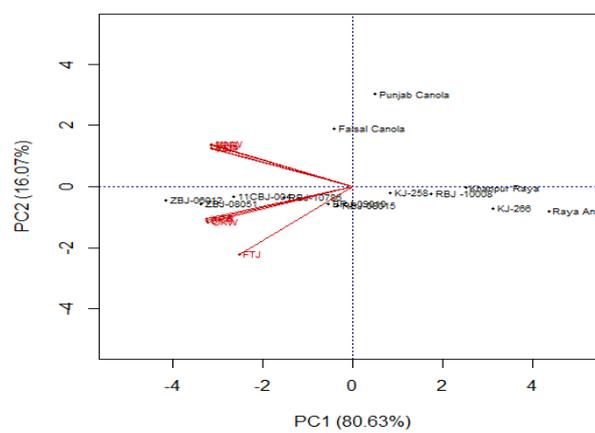


Fig. 3. Bi-plot of genotypes for seed yield at all locations

*Days to maturity of genotypes at all locations:*

The bi-plot for days to maturity at all eight locations presented in Fig. 4 showed the contribution of first two principle components explaining 99.2% of total variation. The bi-plot showed that ZBJ-06012 and ZBJ-0851 was matured in least days as compared to *B. napus* canola cultivars and non-canola mustard cultivars across at all eight locations. *B. napus* canola cultivars Faisal canola and Punjab canola showed highest days to maturity.

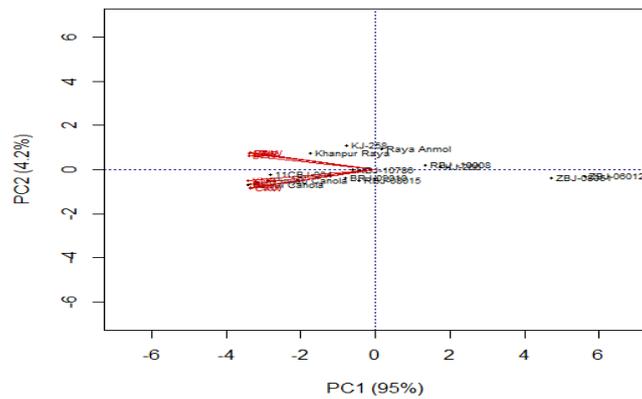


Fig. 4. Bi-plot of genotypes for days to maturity at all locations

*Oil content of genotypes at all locations:*

The bi-plot for oil content at all eight locations presented in Fig. 5 showed the contribution of first two principle components explaining 93.28% of total variation. The bi-plot showed that RBJ-10786 produced highest oil content due to bold seed size. KJ- 266, ZBJ-06012, ZBJ-0851, Faisal canola and Punjab canola produced at par oil content to RBJ-10786.

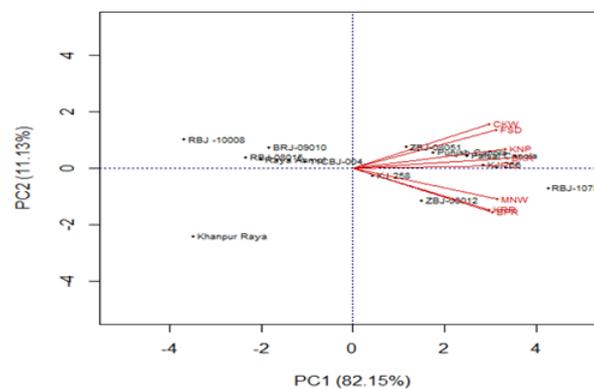


Fig. 5. Bi-plot of genotypes for oil content at all locations

Results presented in Fig. 6 for oil content, Erucic acid and glucosinolates are mean values obtained after analysis of samples from eight locations during 2013 and 2014. Oil content of the promising mustard canola lines was also comparable or equivalent to currently grown *B. napus* cultivars and non-canola mustard cultivars. Glucosinolates contents and erucic acid percentage were found in canola quality range. The promising line ZBJ-06012 had the erucic acid value of 1.2% and glucosinolates 23.25  $\mu$  mole/g oil free meal with 42 % oil content while the ZBJ-08051 possessed erucic acid 0.22% and glucosinolates 27.30  $\mu$  mole/g oil free meal with 40 % oil content. Przybylski *et al.*, (2005) explained that canola oil varieties contains less than 2% erucic acid and the level of glucosinolates in the oil free meal has been less than 30 mmol/g, resulting in better meal quality. Jham *et al.*, (2009) illustrated that less content of erucic acid are helpful to cure the cardiac problems. The promising line ZBJ-06012 had equal or higher meal protein, due to yellow seed coat. The meal quality was also found superior to the current *B. napus* cultivars.

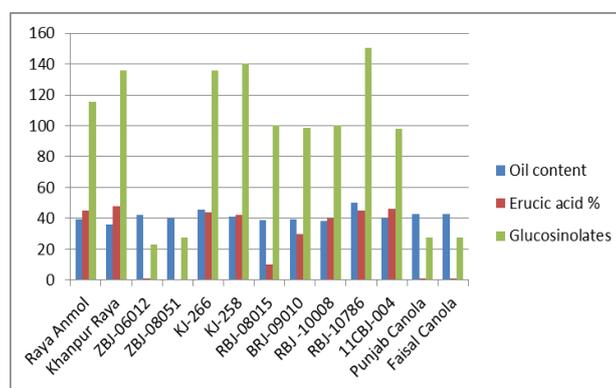


Fig. 6. Mean qualitative values

Table 2. Disease Reaction of ZBJ-06012 and ZBJ-08051 at ORI and PPRI, Faisalabad, Pakistan during 2012-13 and 2013-14.

Variety/Line	Disease intensity		Average disease %age	
	Alternaria Blight (0-9)	Powdery Mildew%	Downey Mildew%	White Rust%
ZBJ-06012	2(HR)	0	0	0
ZBJ-08051	4(MR)	0	0	0

\* 0 = Resistant; 9 = Susceptible; HR=highly resistant; MR=moderately resistant; ORI= Oilseeds Research Institute; PPRI= Plant Protection Research Institute

The major advantages of non-shattering, early maturity, disease and drought tolerant cultivars are their wider adaptability in dry areas. Cultivars having short grain filling period at the reproductive phase are best suitable for survival under water stress conditions (NAWAZ *et al.*, 2013). Disease reaction of promising mustard canola lines were also shown in Table 2. Non-shattering trait of mustard canola lines will provide a cost savings in the country. Due to early

maturity, these lines also escaped from aphid attack. Punjab Seed Council, Pakistan had approved promising mustard canola line ZBJ-06012 with new name AARI canola as variety in 2016 for general cultivation in Punjab province (Pakistan).

During last decade, the breeding of brassica has mainly focused on improving quality and seed yield. Future challenges demand further development of high yielding, short duration and aphid tolerant along with high oil content varieties/hybrids of *B. juncea*. There is a great potential of exploiting genetic variability in the existing *B. juncea* material to achieve the aforesaid goals by using conventional plant breeding techniques.

### CONCLUSIONS

The marvelous increase in oilseed production will be achieved by developing Brassica varieties having good quality edible oil, high seed yield, improved production technology, wider adaptability and procurement assurance. Improvement in mustard can be succeeded by introducing new high potential canola quality mustard cultivars in arid areas of Thal and Cholistan which are lying mostly barren due to water scarcity. *Brassica juncea* possesses drought tolerance and good adaptability for arid areas, hence proved to be a better choice for Thal and Cholistan growers. Canola quality ZBJ-06012 and ZBJ-08051 have been found as an appropriate solution due to their distinguished drought tolerance trait.

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**OBEZBEĐIVANJE HRANE U ARIDNIM OBLASTIMA PAKISTANA  
GAJENJEM NOVODOBIJENE *Brassica juncea* L., TOLERANTNE NA SUŠU  
I KRAĆE VEGETACIJE**

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Izvod

Bezbednost hrane je ključno globalno pitanje, posebno u zemljama u razvoju poput Pakistana. S obzirom na to da je jestivo ulje esencijalno u ishrani, njegov stalni nedostatak i veliki uvoz za zadovoljavanje domaćih zahteva, dovodi do toga da je jestivo ulje druga uvozna stavka, posle naftnih proizvoda. Cilj ovog rada je kvalitativna i kvantitativna ocena novo razvijenih linija ZBJ-06012 i ZBJ-08051 (*Brassica juncea*), tolerantnih na sušu i skraćene vegetacije, zbog prevazilaženja nepovoljne situacije sa jestivim uljem u zemlji. Trinaest linija je ocenjivano u RCBD dizajnu za prinos zrna, kvalitet ulja, period sazrevanja i tolerantnost na sušu u različitim agroklimatskim zonama, u uslovima sa i bez navodnjavanja u Pendžab provinciji, na osam lokaliteta u mikro ogledima tokom Rabi sezone u 2012-13 i 2013-14. Trenutno gajeni varijeteti Khanpur Raya i Anmol Raya korišćeni su kao standardi. *Brassica napus* kultivari *Punjab canola* i *Faisal canola*, su takođe uključeni u ogled. Svi podaci su analizirani PCA analizom u cilju izdvajanja linija sa najboljim performansama. Prosečan prinos zrna je upoređivan LSD testom za nivo značajnosti od 5%. Linije ZBJ-06012 i ZBJ-08051 su pokazale dobru adaptabilnost, rano sazrevanje, nisu se osipale, bile su tolerantne na bolesti i sušu i imale su visok potencijal za prinos u poređenju sa trenutno gajenim *Brassica napus* kultivarima *Punjab canola* i *Faisal canola*. Postoji veliki potencijal u genetičkoj varijabilnosti postojećeg *B. juncea* materijala za stvaranje visoko prinostnih kultivara, sa kratkom vegetacijom, tolerantnih na lisne vaši, konvencionalnim oplemenjivačkim metodama.

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