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*Original scientific paper*

# MODE OF INHERITANCE OF DRY MATTER CONTENT IN ONION (*Allium cepa* L.) BULB

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Onion dry matter content is very important in terms of processing. The study was undertaken in order to investigate dry matter content inheritance pattern in fresh onion bulb. Five divergent onion genotypes, originating from different geographical areas, have been crossed. Full diallel crossing method (without reciprocals) was applied in order to obtain $F_1$ and $F_2$ generation offspring. Field trial including parents and $F_1$ and $F_2$ hybrids was performed at the Institute for Vegetable Crops experimental plot, Smederevska Palanka. The trial was conducted in randomized blocks, with five replications. Intermediate inheritance pattern prevailed for both $F_1$

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and $F_2$ generation. Additive genetic component value was higher than dominant for both $F_1$ and $F_2$ generation, which implies additive effect of genes. Hybrid combination PR x BB was characterized by the highest heterosis value (11.85%). Better general combining abilities were confirmed for three lines in comparison with other lines, whereas special combining abilities were significant for one $F_1$ hybrid. Neither general nor special combining abilities were significant for $F_2$ generation.

*Key words:* combining abilities, dry matter content, heterosis, onion

## INTRODUCTION

Amongst the species of genus *Allium*, onion is the most important and high quality of the bulb is an imperative for breeders. Onion dry matter content is very important in terms of processing, owing to its negative correlation to quantity of fresh bulbs required for dry onion production. Dry matter content also influences shelf life and the quality of the bulbs (DEBAENE e*t al.*, 1999, GRIFFITHS *et al.*, 2002, KUMAR *et al.*, 2007, ZDRAVKOVIĆ *et al.*, 2010).

An understanding of dry matter content mode of inheritance is an important task for breeders. The estimate of combining abilities of the starting material makes the choice of parental genotypes less difficult. The selection should be focused on the traits characterized by higher heritability (ORTIZ *et al.*, 2001).

This study was undertaken in order to investigate dry matter content inheritance pattern in onion bulbs.

## MATERIAL AND METHODS

Five onion genotypes (Makoi bronzi, Piroška, AC101/Zlatno gnezdo, Jasenički crveni and Bunkino beo), differing in geographical origin, have been intercrossed.

Comparative field trial including parents, $F_1$ and $F_2$ generation, has been conducted at the experimental field of Institute for Vegetable Crops, Smederevska Palanka, Serbia. The trial was set in complete random block design, with five replications. Each replication included 30 plants. Standard agro technical procedures have been applied. Bulb dry matter content was determined by standard procedure.

Dry matter content inheritance pattern was estimated using the model that includes parents, $F_1$ and $F_2$ generation (BOROJEVIĆ, 1986). Genetic variance was partitioned by HAYMAN (1954) and MATHER and JINKS (1971) statistical methods. Combining ability analysis was performed by Method 2, Mathematical model 1 (GRIFFING, 1956).

## RESULTS AND DISCUSSION

Among the parents, the average bulb dry matter content varied in the range from 9.45% (Makoi bronzi) to 15.69% (Bunkino beo). For $F_1$ generation, the lowest average content of dry matter has been determined in hybrid combination Makoi bronzi x Piroška (10.19%), whereas the highest dry matter content had hybrid Piroška x Bunkino beo (15.05%).

The content of dry matter in $F_2$ generation varied from 10.53% (Makoi bronzi x Piroška) to 14.85% (Jasenički crveni x Bunkino beo), Table 1. WAL and CORGAN (1999) pointed out higher dry matter content in bulbs of white onions, which has been confirmed in our research.

Variability expressed through coefficient of variation (*Cv*) was the lowest for line Bukino beo (0.37%) and the highest for Makoi bronzi (7.09%), concerning parents. For $F_1$ generation, *Cv* fell in the range from 2.57% (AC 101 x Bunkino beo) to 5.69% (Makoi bronzi x Jasenički crveni). Coefficients of variation calculated for $F_2$ generation were higher, as expected (Table 1). High variability, as well as significant influence of environment, agro-technology and processing on onion dry matter content have been reported by RANDLE (1997) and HENDRIKSEN and HANSEN (2001).

The most common mode of inheritance of dry matter content was intermediary, for both studied generations. The intermediary mode of inheritance has been confirmed for seven hybrid combinations in $F_1$ generation, as well as for five hybrid combinations in $F_2$ generation. Besides this mode of inheritance, the partial domination of the worse and domination of better parent has been observed (Table1).

Concerning $F_1$ generation, statistically significant heterotic effect has been found for hybrid combination Piroška x Bunkino beo only (11.85%), whereas in $F_2$ generation not a single hybrid had significant values of heterosis (Table 1). Low heterosis effect for dry matter content in bulbs has been found by MADALGAR and BOJAPPA (1986) and PANAJOTOVIĆ (1986).

The additive variance component (*D*) was higher than the dominant ($H_1$ and $H_2$) in $F_1$ and $F_2$ generation; therefore, the most of the genetic variability belongs to the additive gene reaction (Table 2). The negative *F* value shows that recessive alleles have higher impact in inheritance of this trait. The distribution of dominant and recessive alleles was not equal ($H_2/4H_1$ = 0.19 and 0.13). For hybrid $F_1$ generation, narrow sense heritability was 0.90 and broader sense heritability was 0.95. Values for heritability in $F_2$ generation were lower. High heritability values for dry matter content implying the genetic effects on the trait have been found also by RANDLE (1997) and PAVLOVIĆ *et al.* (2006).

Total number of dominant and recessive alleles ratio (Kd/Kr) was lower than 1 for both generations, implying higher effect of recessive alleles in inheritance of dry matter content in onion bulbs. The average level of dominance ($\sqrt{H_1/D}$ = 0.43 and 0.31) was lower than 1 for all crossing combinations, which indicated dominance as the mode of inheritance for dry matter content.

Three parental lines had significant GCA values (Table 4). Makoi bronzi and Piroška had negative significant values in $F_1$ generation, while the best GCA had Bunkino beo, which was ranked the highest. The results were similar in $F_2$ generation; however, the value for Piroška was insignificant.

*Table 1. Mean value ($\bar{X}$), standard error (Sx), coefficient of variation (Cv), mode of inheritance, absolute and relative heterosis (Ha and Hr) for onion bulb dry matter content for parents, $F_1$ and $F_2$ hybrids.*

| Genotypes | **$F_1$** | | $F_2$ | | Ha | | **Hr** | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$ ±Sx | Cv (%) | $\bar{x}$ ±Sx | Cv (%) | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| Makoi bronzi | 9.45 | 5.94 | 9.45 | 5.94 | | | | |
| (MB) | 1.58 | | 1.58 | | | | | |
| MB x PR | 10.19$^{i}$ | 3.34 | 10.53 | 9.33 | -0.14 | 0.19 | -1.37 | 1.83 |
| | 2.84 | | 0.94 | | | | | |
| MB x AC 101 | 11.63$^{i}$ | 3.94 | 11.20$^{i}$ | 4.75 | 0.33 | -0.21 | 2.86 | -1.83 |
| | 3.20 | | 2.67 | | | | | |
| MB x JC | 10.82$^{Pd}$ | 5.69 | 10.82$^{Pd-}$ | 5.69 | -0.92 | -0.92 | -7.83 | -7.83 |
| | $^{-}$2.20 | | 2.20 | | | | | |
| MB x BB | 12.34$^{i}$ | 3.04 | 12.56$^{i}$ | 8.22 | 0.23 | -0.01 | -1.83 | -0.07 |
| | 3.83 | | 1.99 | | | | | |
| Piroska (PR) | 11.22 | 5.89 | 11.22 | 5.89 | | | | |
| | 2.29 | | 2.29 | | | | | |
| PR x AC 101 | 12.31$^{i}$ | 5.74 | 12.33$^{i}$ | 8.50 | 0.10 | 0.12 | 0.84 | 0.95 |
| | 3.16 | | 1.81 | | | | | |
| PR x JC | 12.63$^{i}$ | 4.74 | 12.83$^{i}$ | 8.80 | 0.01 | 0.21 | 0.04 | 1.65 |
| | 3.29 | | 1.90 | | | | | |
| PR x BB | 15.05$^{d+}$ | 4.17 | 14.80$^{d+}$ | 2.48 | 1.60$^{**}$ | 1.35 | 11.85 | 9.99 |
| | 4.49 | | 5.05 | | | | | |
| AC 101 | 13.20 | 5.41 | 13.20 | 5.41 | | | | |
| | 3.27 | | 3.27 | | | | | |
| AC 101 x JC | 12.72 | 4.97 | 12.45 | 10.61 | -0.89 | -1.17 | -6.57 | -8.60 |
| | 3.24 | | 1.27 | | | | | |
| AC 101 x BB | 14.40$^{i}$ | 2.57 | 14.27$^{i}$ | 4.64 | -0.05 | -0.18 | -0.33 | -1.26 |
| | 4.86 | | 3.99 | | | | | |
| Jasenicki crveni | 14.03 | 7.09 | 14.03 | 7.09 | | | | |
| (JC) | 2.97 | | 2.97 | | | | | |
| JC x BB | 14.85$^{i}$ | 4.08 | 14.85 | 5.83 | 0.00 | -0.01 | 0.02 | -0.08 |
| | 4.45 | | 3.77 | | | | | |
| Bunkino beo (BB) | 15.69 | 0.37 | 15.69 | 0.37 | | | | |
| | 6.25 | | 6.25 | | | | | |

$F_1$ $lsd_{0.05}$ = 1.09   $F_2$ $lsd_{0.05}$ = 1.59   $lsd_{0.01}$ = 1.44   $lsd_{00.1}$ = 2.07

$^{i}$ intermediary inheritance, $^{Pd}$ partial dominance, $^{d}$ dominance, $^{Sd}$ superdominance

*Table 2. Components of genetic variance for onion bulb dry matter content*

| Components | Value $F_1$ | Value $F_2$ |
|---|---|---|
| $D$ | 5.782 | 5.260 |
| $H_1$ | 1.083 | 0.560 |
| $H_2$ | 0.827 | 0.300 |
| $F$ | -0.595 | -0.460 |
| $E$ | 0.147 | 0.303 |
| $H_2/4H_1$ | 0.191 | 0.134 |
| $\sqrt{H_1/D}$ | 0.433 | 0.315 |
| $Kd/Kr$ | 0.787 | 0.770 |
| $hn^2$ | 0.90 | 0.89 |
| $hb^2$ | 0.95 | 0.91 |

Analysis of combining abilities for dry matter content in onion bulbs showed significant values for GCA (general combining abilities) only, while the values for SCA (special combining abilities) were insignificant. GCA value of 35.6 for $F_1$ generation and 41.9 for $F_2$ generation were higher that the corresponding values of SCA (Table 3), which could be explained by prevalence of additive gene effect in inheritance of the trait. Similar results have been reported by PANAJOTOVIĆ (1986).

*Table 3. Analysis of variance for combining abilities for onion bulb dry matter content*

| Source of variation | df | (SS) | | (MS) | | F-exp | |
|---|---|---|---|---|---|---|---|
| | | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| GCA | 4 | 44.82 | 43.56 | 11.20 | 10.89 | $76.08^{**}$ | $35.97^{**}$ |
| SCA | 10 | 3.14 | 2.59 | 0.31 | 0.25 | 2.13 | 0.85 |
| error | 28 | | | 0.14 | 0.30 | | |
| GCA/SCA | | | | 35.38 | 41.92 | | |

GCA $F_{0.05} = 2.71$ $F_{0.01} = 4.07$
SCA $F_{0.05} = 2.19$ $F_{0.01} = 3.03$

The highest value of SCA for $F_1$ generation expressed hybrid Piroška x Bunkino beo. It was the only hybrid with significant SCA value. For $F_2$ generation none of the hybrid combinations showed significant values for SCA (Table 5). Low number of combinations with good SCA could be explained by high additive genetic variance. PANAJOTOVIĆ (1986) reported similar results. On the contrary, HAVEY and RANDLE (1996) reported significant values for both GCA and SCA.

*Table 4. GCA values for onion bulb dry matter content in parental lines*

| Parents | Value of SCA $F_1$ | **Rank** | Se | B Value of SCA $F_2$ | **Rank** | **Se** |
|---|---|---|---|---|---|---|
| MB | $-1.760^{**}$ | 5 | | -1.732 | 5 | |
| PR | $-0.514^{*}$ | 4 | | -0.446 | 4 | |
| AC101 | 0.182 | 3 | 0.205 | 0.073 | 3 | 0.294 |
| JC | 0.408 | 2 | | 0.420 | 2 | |
| BB | $1.684^{**}$ | 1 | | 1.684 | 1 | |

$lsd_{0.05}$= 0.410 $lsd_{0.05}$=0.588
$lsd_{0.01}$= 0.545 $lsd_{0.01}$=0.782
*Se* - standard error

*Table 5. SCA values for onion bulb dry matter content in $F_1$ and $F_2$ generation*

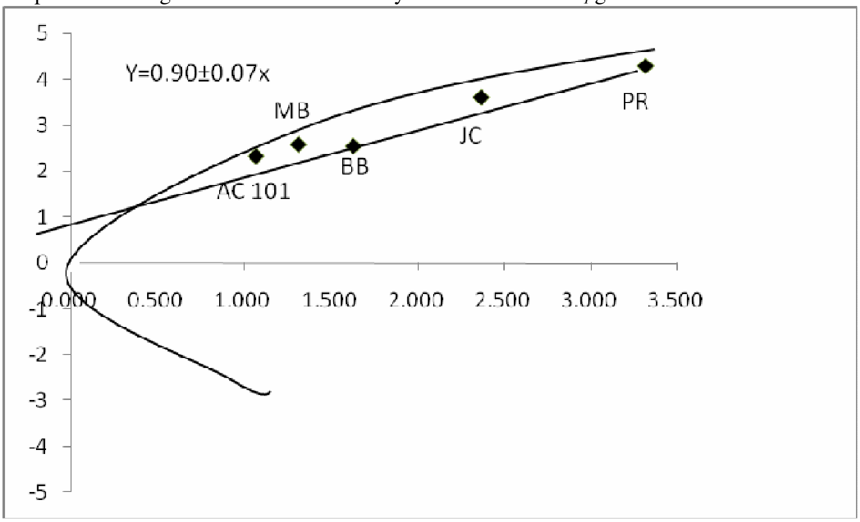
| Genotypes | SCA $F_1$ | Se | SCA $F_2$ | Se |
|---|---|---|---|---|
| MB x PR | -0.236 | | 0.032 | |
| MB x AC 101 | 0.526 | | 0.102 | |
| MB x JC | -0.532 | | -0.544 | |
| MB x BB | -0.289 | | -0.068 | |
| PR x AC 101 | -0.056 | 0.458 | 0.026 | 4.257 |
| PR x JC | 0.030 | | 0.182 | |
| PR x BB | $1.174^{*}$ | | 0.885 | |
| AC 101 x JC | -0.572 | | -0.724 | |
| AC 101 x BB | -0.172 | | -0.168 | |
| JC x BB | 0.0581 | | 0.064 | |

$lsd_{0.05}$ =0.917 $lsd_{0.05}$ = 1.315
$lsd_{0.01}$ = 1.220 $lsd_{0.01}$ = 1.749
*Se* - standard error

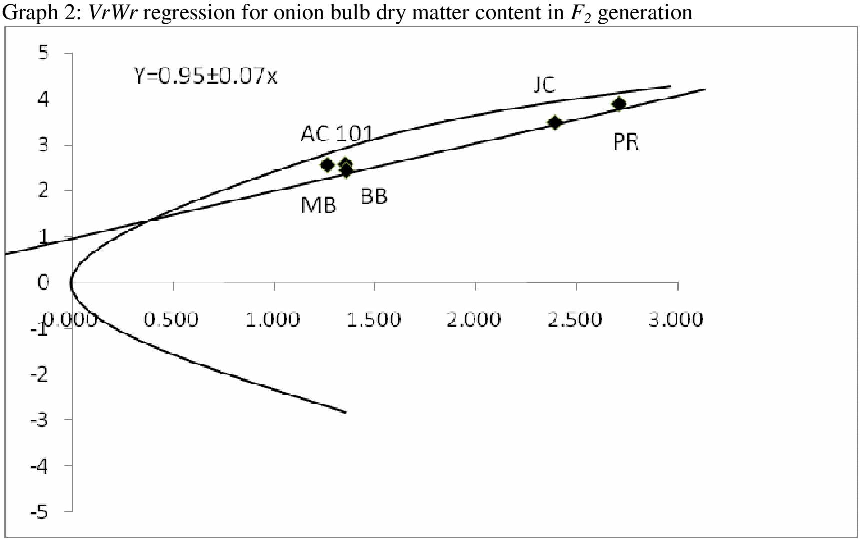
Regression coefficients (*b*=0.90 and 0.95) were not significantly different than 1, implying the absence of interallele gene reaction in inheritance of the dry matter content.

The regression line was very close to the limiting parabola for both generations, which proves additive gene reaction in dry matter content inheritance (Graph 1 and 2). The average of the expected regression line with *Wr* axis was above the coordinate beginning, which is one of the parameters that imply partial dominance as the mode of inheritance of this trait.

Graph 1: *VrWr* regression for onion bulb dry matter content in $F_1$ generation




Graph 2: *VrWr* regression for onion bulb dry matter content in $F_2$ generation




Parental genotype closest to the coordinate beginning was the genotype with the highest number of dominant genes; in $F_1$ generation it was AC 101 and in $F_2$ generation Makoi bronzi. The highest number of recessive genes in both generations had genotype Piroška.

## CONCLUSION

Results obtained in our experiments did show that the most common mode of inheritance of onion dry matter content was intermediary. Statistically significant heterosis value has been found only in hybrid combination Piroška x Bunkino beo in $F_1$ generation, whereas in $F_2$ generation none of the hybrids had significant values of heterosis. The best general combiner was Bunkino beo. The highest value of SCA in $F_1$ and $F_2$ generation had hybrid Piroška x Bunkino beo.

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## NAČIN NASLEĐIVANJA UKUPNOG SADRŽAJA SUVE MATERIJE U LUKOVICI CRNOG LUKA (*Allium cepa* L.)

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I z v o d

Sadržaj suve materije je izuzetno važan sa aspekta dehidratacije crnog luka u prehrambenoj industriji. U cilju ispitivanja načina nasleđivanja ove osobine izvršeno je ukrštanje između pet divergentnih genotipova crnog luka, različitog geografskog porekla. Primenjen je metod punog dialela bez recipročnih ukrštanja, radi dobijanja potomstva $F_1$ i $F_2$ generacije. Poljski ogled sa roditeljima i hibridima $F_1$ i $F_2$ generacije postavljen je po slučajnom blok sistemu u pet ponavljanja u Institutu za povrtarstvo, Smederevska Palanka.

Najčešći način nasleđivanja bilo je intermedijarno posmatrano u obe generacije ispitivanja. Vrednost aditivne genetičke komponente je veća od dominantne u oba analizirana generacijska nivoa ($F_1$ i $F_2$), što ukazuje da veći deo genetičke varijabilnosti pripada aditivnom delovanju gena. Najveća vrednost za heterozis (11,85%) izračunata je kod hibridne kombinacije PR x BB. Signifikantne vrednosti OKS su izračunate kod tri linije, a PKS kod jednog $F_1$ hibrida. U $F_2$ generaciji nisu utvrđene signifikantne vrednosti.

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