ISSN 1313 - 8820
Volume 5, Number 4
December 2013

AGRICULTURAL SCIENCE AND TECHNOLOGY

2013

An International Journal Published by Faculty of Agriculture,
Trakia University, Stara Zagora, Bulgaria

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The journal is accepted to be indexed with the support of a project № BG051PO001-3.3.05-0001 "Science and business" financed by Operational Programme "Human Resources Development" of EU. The title has been suggested to be included in SCOPUS (Elsevier) and Electronic Journals Submission Form (Thomson Reuters).

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AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 5, No 4, pp 432 - 437, 2013

Productivity of green beans, irrigated at different pre-irrigation soil moisture

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Abstract. *The aim of the study was to establish productivity of green bean, variety "Strike" irrigated at different pre-irrigation soil moisture. The field experiment was conducted during the period 2010 – 2012 on the experimental field of Agricultural University, Plovdiv. The tested variants are as follows: 1) no irrigation; variants 2) 3) 4) and 5) irrigated at soil moisture of 60, 70, 80 and 90% of FC. The irrigation rate for each of the variants is calculated to moisten the soil layer 0-60 cm. The type of irrigation is by gravity on short closed furrow. Summary data showed that without irrigation the average yield is 4248 kg/ha, with a range of 1144 kg/ha in dry years to 8393 kg/ha in medium wet years. Best results are obtained by maintaining soil moisture above/up to 80% of FC, and the yield was more than three times higher than that without irrigation and the mean value is 14805 kg/ha, varying from 12046 kg/ha to 16683 kg/ha.*

Keywords: green bean, irrigation regime, water deficit, yield

Introduction

Green bean is one of the important vegetable crops grown in Bulgaria. It has short vegetation period and well expressed plasticity to amendment abiotic factors, which allows phased sowing from mid-May to mid-July. Because of this, it can be used as a material for the cannery from the beginning of July till the first hoarfrosts. On the other hand, it is also suitable for using in crop rotations as sown culture. Unlike most vegetable crops, in the conditions of our country green beans may form yield without irrigation, which varies in wide range, depending on the amount and the distribution of vegetation precipitation. Therefore, irrigation is a major activity of agrotechnics of the crop and optimization of the irrigation rate is a prerequisite for increasing its efficiency.

All studies show in a definite way that the yield from optimally irrigated green beans grow significantly and stabilize. According to Helyes et al. (2005), in the settings of Hungary yield at non-irrigated conditions is 1,9 – 2,8 t/ha, according to Mehta et al. (1987), optimal irrigation for the region of Hisar (India) increases the yield up to 265%. Very high values of the additional yield (2.1 – 3.9 times) in the result of irrigation are indicated by Muñoz-Perea et al. (2007). One of the first and very important steps in optimizing the irrigation rate of each crop is the correct determination of pre-irrigation humidity and width of the soil layer, which is wetted at irrigation. Subsequently the possibilities of further reduction or variation according to the sensitivity of plants in the various stages of vegetation are explored. As a result, the economic effect increases, by reducing the cost of irrigation and some minor losses of yield.

According to Delibaltov and Sarkizov (1974) beans grown on cinnamon forest soils in the region of Pazardzhik, should be irrigated at pre-irrigation humidity of 70 to 80% of FC, which is related to providing 3 irrigations on average. For alluvial soils in the region of Buzau (South-East Romania), green beans should be irrigated at pre-irrigation humidity of 70% of FC, with a rate of 40 to 50 mm. This irrigation rate ensures the obtaining of high yields in the range of 11100–14800 kg/ha, and that in row spacing of 0.8 m (Albient, 1976). Based on studies conducted in Mexico, Acosta Diaz et al. (1997) found that the optimal pre-irrigation humidity for beans is 75% of FC. For the same part of the world (Havana, Cuba), Gilart Perez (1975) recommended beans to be irrigated at soil moisture of 80% of FC, and depending on the type of the year from 2–4 to 8–9 irrigations are needed. The same pre-irrigation humidity is indicated by El-Shamma et al. (2000), while in the conditions of Sao Paolo (Brazil), Bizari et al. (2009) considered that watering green beans should be performed at higher soil moisture available – 90% of FC.

Although some authors recommends as a compromise variant irrigation at too low soil moisture available (60–65% of FC) and others suggests that maintenance of high soil moisture (90% of FC or daily irrigation with moistening the soil to FC), the majority of scientists were united in recommending optimal pre-irrigation humidity in the range of 70–80% of FC, apart from the soil and climatic conditions.

The aim of this paper is to investigate the influence of different pre-irrigation soil moisture on the productivity of green beans, grown in the region of Plovdiv and on this basis to determine the most appropriate one.

Material and methods

The experimental work was conducted during the period 2010 – 2012 at the experimental base of Agricultural University (AU), Plovdiv on alluvial-meadow (formerly waterlogged) soil. The experiment is according to the block method in four replications, the size of the experimental plots is 17.5 m^2, and the vintage – 10.0 m^2. The variety used is a low-growing "Strike". The scheme of sowing is 0.5 x 0.05 m, which ensures stand density of 400000 plants per 1 ha. The following variants are tested: 1) without irrigation, 2), 3), 4) and 5) irrigated at humidity 60, 70, 80 and 90% of FC. These values of pre-irrigation soil moisture are valid for the layer of 0–40 cm. Irrigation is done by gravity on short closed furrows, and the irrigation rate for each of the variants is calculated for moistening to FC of the soil layer from 0 to 60 cm. Hypothetically, in the conditions of the experiment as optimum in irrigation is received variant 4 (80% of FC), therefore at the analysis of the results it and the non-irrigated variant (variant 1) were used as controls. The data for yield per

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variants and repeats are processed by the software product ANOVA-1 (Penchev, 1988), and having been established warranted of the differences between the variants. The productivity of irrigation rate is determined, as the ratio of the additional yield obtained due to the applied irrigation regime and obtained irrigation rate.

Results and discussion

The influence of the applied irrigation regime on the productivity of the green beans depends largely on the meteorological conditions in a particular vegetation. In this connection statistical evaluation of the experimental years is made in terms of precipitation and temperature amount for the period May – July, and the data used are from multi-year period. The results are presented in Table 1 and in Figures 1 and 2. According to them, the first experimental year is medium wet with probability 24.8% and rainfall of 197.8 mm. To phase "bud formation" optimal soil moisture is provided naturally. During the periods flowering and initial formation of pods, rainfall amounts are insignificant and the 107.4 mm that fell at the end of the harvesting period are without agronomic importance.

The distribution of vegetation rainfalls in the second year of the experiment (2011) is similar, 52.6% of them falls till the beginning of the reproductive period. During the flowering period there is drought, and the 37.2 mm that fell at the end of vegetation do not have any influence on the crop development either. This year is characterized as dry with a probability of 89.2% and the amount of vegetation rainfalls is 96.9 mm. Although the levels are significant (205.6 mm), precipitations during the third experimental year in 2012 are the most unevenly distributed as 97.7% of them fall in the early stages of crop vegetation (up to phase "bud formation"). The lack of rainfall during the generative period, combined with high air temperatures and low atmospheric humidity, lead to significant differences between the tested variants in terms of obtained yield. The year was characterized as medium humid with a probability of 23.5%.

Regarding the air temperature for the period May–July, the first two years were medium warm, with a probability 30.4 and 21.6%, respectively, and the third one is warm (P = 4.9%).

Differences in the weather conditions during the three experimental years affected the elements of the irrigation regime by variants. It is essential and for the effect on the yield, especially in the non-irrigated variant, to satisfy the needs of the plants for water entirely from precipitations.

Table 2 presents data about the number of realized irrigations by periods and the size of the irrigation rates and irrigation depths by variants. To maintain pre-irrigation soil moisture 60% of FC, during the three experimental years it was achieved by one irrigation at the end of the period of fructification, the size of the irrigation rate is 95 mm on average. In more extensive irrigation regime (70% of FC) the influence of the type of the year on the number and distribution of the

Table 1. Probability of meteorological factors for the V – VII period

Factor		Average	2010	2011	2012
ΣN	mm	170.2 mm (for period of 101 years)	197.8	96.9	205.6
	P %		24.8	89.2	23.5
ΣT°	°C	1910°C (for period of 101 years)	1960	1993	2089
	P %		30.4	21.6	4.9

* ΣN – precipitations; ΣT° – temperature; P % – probability of meteorological factors

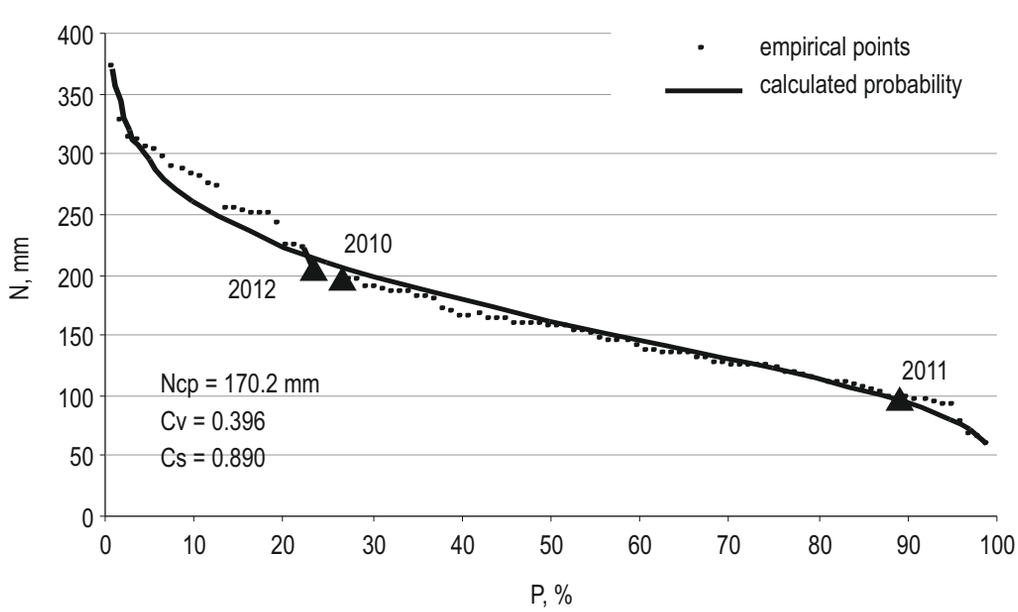

Figure 1 Precipitation probability for V–VII period

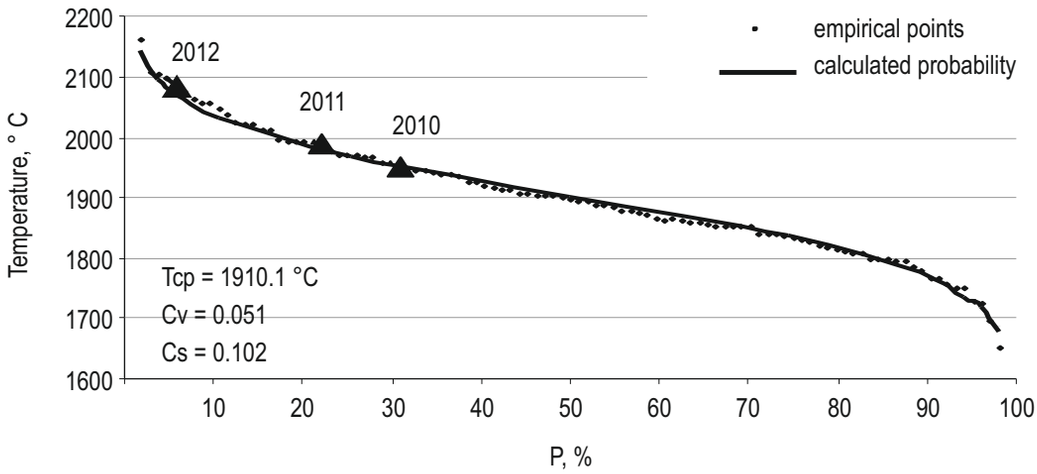

Figure 2 Probability of temperature sum total for V–VII period

Table 2. Irrigation depth, number of irrigations and their distribution during the vegetation period by variants

Year	Period of vegetation		Variant			
			60%FC	70%FC	80%FC	90%FC
2010	bud – flowering	number	–	–	1	1
		m*	–	–	46.0	46.0
	flowering – pod formation	number	–	–	1	1
		m	–	–	50.9	32.9
	pod formation – harvesting	number	1	1	1	4
		m	95.4	76.4	51.8	137.3
	Number of irrigations		1	1	3	6
	Irrigation depth (mm)		95.4	76.4	148.7	216.2
2011	sowing – bud	number	–	–	1	4
		m	–	–	56.7	106.8
	bud – flowering	number	–	1	1	2
		m	–	66.6	46.9	53.4
	flowering – pod formation	number	–	–	2	2
		m	–	–	97.0	48.5
	pod formation – harvesting	number	1	2	2	4
		m	90.4	141.3	102.7	106.9
	Number of irrigations		1	3	6	12
	Irrigation depth (mm)		90.4	207.9	303.3	315.6
2012	sowing – bud	number	–	–	–	1
		m	–	–	–	24.7
	bud – flowering	number	–	–	1	2
		m	–	–	51.8	49.4
	flowering – pod formation	number	–	1	2	5
		m	–	74.0	98.6	144.0
	pod formation – harvesting	number	1	1	2	4
		m	98.6	74.0	103.6	97.9
	Number of irrigations		1	2	5	12
	Irrigation depth (mm)		98.6	148.0	254.0	316.0

*m – Irrigation rate (mm)

irrigations is already in place, as through the wettest of the three years, 2010 has brought a single irrigation during fructification period with size 76.4 mm. Due to a significant drought in the early reproductive period in the second experimental year (2011) one irrigation was made during "bud formation-flowering" and then during the pod formation and growth of bean two irrigations were made. In the extreme year 2012 that irrigation regime is achieved by two irrigations, respectively, during a "flowering-fructification" and at the pods formation. The size of the irrigation rate in the second year is 207.9 mm, and in 2012 – 148.0 mm.

For the conditions of the first experimental year, at variant 4 (80% of FC) the size of the irrigation rate is 148,7 mm, as the irrigation regime is realized by using three irrigations given during the period "bud formation", "flowering-pod formation" and "growth of pods." In the second and third experimental years this variant is realized by 5 irrigations during the reproductive period – 1 at "bud formation" and two at "flowering-pod formation" and "growth of pods." In 2011 one irrigation was realized during the vegetation period. The size of the irrigation rate in 2011 is 303.3 mm, while in the experimental 2012 – 254.0 mm. Maintaining high pre-irrigation soil humidity (over 90% of FC) is associated with a significant intensification of irrigation, with exception of the first year, when 6 irrigations are made in 2011 and in 2012 the number of irrigations is 12, and the size of the irrigation rate per years is respectively 216.2 mm, 315.6 mm and 316.0 mm.

Data on productivity of green beans, irrigated at different pre-irrigation humidity are listed in Table 3. As in the vegetation period of 2010 precipitation is significantly larger than the experimental 2011, the yield from non-irrigated conditions differs significantly. Though rainfall amount in 2012 is the highest, it is unevenly distributed, combined with higher average daily temperatures and low atmospheric humidity, the crop is placed in the most extreme conditions during its critical periods for the entire experimental period. In 2010 the yield at non-irrigation rate is with amount of 8393 kg/ha and is about 50% smaller than in variant 4 (80% of FC), and in 2011 it is with amount of 3210 kg/ha or 19%. Logically the lowest yield is in 2012 which amounts to 1144 kg/ha, or only 9.5% of that in variant 4.

Irrigation at different pre-irrigation soil moisture has a significant impact on yield. While maintaining its low level (60% of FC) the yield from non-irrigated bean increased slightly, but the differences are statistically proven. The average increase for the experiment is 27.5 %, or by 1168 kg/ha. Maintaining pre-irrigation humidity above 70% of FC had a substantial impact on the yield, as the mean for experimental period increased by 2988 kg/ha or 70.3% compared with non-irrigated beans. In medium wet years (2010) yield reaches 65% of the maximum, and in extreme years (2012) – below 30%. In older literature sources it is recommended to maintain this pre-

Table. 3 Influence of pre-irrigation soil moisture on the green bean productivity

Variant		Yield (kg/ha)	to variant 1			to variant 2		
			±Y (kg/ha)	%	Warranted	±Y (kg/ha)	%	Warranted
				2010				
1	no irrigated	8393	St.	100.0	St.	– 7292	53.5	***
2	60% of FC	9243	850	110.1	**	– 6442	58.9	***
3	70% of FC	10089	1696	120.2	***	– 5596	64.3	***
4	80% of FC	15685	7292	186.9	***	St.	100.0	St.
5	90% of FC	15536	7143	185.1	***	– 149	99.1	n.s.
GD: P 5% = 600 kg/ha		1% = 842 kg/ha	0.1% = 1190 kg/ha					
				2011				
1	no irrigated	3207	St	100.0	St.	– 13476	19.2	***
2	60% of FC	4606	1399	143.6	**	– 12077	27.6	***
3	70% of FC	8276	5069	258.1	***	– 8407	49.6	***
4	80% of FC	16683	13476	520.2	***	St.	100.0	St.
5	90% of FC	16453	13246	513.0	***	– 230	98.6	n.s.
GD: P 5% = 872 kg/ha		1% = 1222 kg/ha	P 0.1% = 1727 kg/ha					
				2012				
1	no irrigated	1144	St.	100.0	St.	– 10902	9.5	***
2	60% of FC	2400	1256	209.8	**	– 9646	19.9	***
3	70% of FC	3344	2200	292.3	***	– 8702	27.8	***
4	80% of FC	12046	10902	1053.0	***	St.	100.0	St.
5	90% of FC	12142	10998	1061.4	***	+ 96	100.8	n.s.
GD: P 5% = 806 kg/ha		1% = 1130 kg/ha	0.1% = 1598 kg/ha					
				Average for 2010 – 2012 period				
1	no irrigated	4248	St.	100.0		– 10557	28.7	
2	60% of FC	5416	1168	127.5		– 9388	36.6	
3	70% of FC	7236	2988	170.3		– 7568	48.9	
4	80% of FC	14805	10557	348.5		St.	100.0	
5	90% of FC	14710	10462	346.3		– 94	99.4	

Table. 4 Irrigation depth productivity depending on pre-irrigation soil moisture by years

Variant		Yield (kg/ha)	Additional yield		Irrigation depth		(kg.ha^{-1}.mm^{-1})
			kg/da	%	mm	%	
				2010			
1	no irrigated	8393	St.	St.	–	–	–
2	60% of FC	9243	850	110.1	95.4	0.64	8.91
3	70% of FC	10089	1696	120.2	76.4	0.51	22.20
4	80% of FC	15685	7292	186.9	148.7	1.00	49.04
5	90% of FC	15536	7143	185.1	216.2	1.45	33.04
				2011			
1	no irrigated	3207	St.	St.	–	–	–
2	60% of FC	4606	1399	143.6	90.4	0.30	15.48
3	70% of FC	8276	5069	258.1	207.9	0.69	24.38
4	80% of FC	16683	13476	520.2	303.3	1.00	44.43
5	90% of FC	16453	13246	513.0	315.6	1.04	41.97
				2012			
1	no irrigated	1144	St.	St.	–	–	–
2	60% of FC	2400	1256	209.8	98.6	0.39	12.74
3	70% of FC	3344	2200	292.3	148.0	0.58	14.86
4	80% of FC	12046	10902	1053.0	254.0	1.00	42.92
5	90% of FC	12142	10998	1061.4	316.0	1.24	34.80

*IWUE – irrigation water use efficiency

irrigation humidity. For the experiment conditions, it leads to a decrease in the yield with an average amount of 7568 kg/ha, or 48.9% of yield obtained by maintaining pre-irrigation humidity 80% of FC. This confirms the hypothesis that in 80% of FC the highest yield is achieved.

By optimizing irrigation regime yield increases in 2010, its amount goes to 15685 kg/ha, i.e. the increase is by 86.9% or 7290 kg/ha compared to non-irrigated beans. In 2011, when vegetation rainfalls are scarce, the yield from optimal irrigation (variant 4) amounts to 16680 kg/ha, which is up to 5 times than that of the non-irrigated variant or 13480 kg/ha. In 2012 the same at 4 variant (80% of FC) has an amount of 12046 kg/ha. The increase in yield is 10902 kg/ha or more than 10 times (1053%). This clearly shows that irrigation by 80% of FC sufficiently mitigated the unfavorable weather conditions and stabilized yield despite the unfavorable climatic conditions during the vegetation period. Maintaining higher soil moisture (over 90% of FC) practically does not lead to further increase of the yield, and the differences with variant 4 are not statistically proven in any of the experimental years.

Table 4 presents the data of productivity of the irrigation rate per variants and years. Figure 3 presents graphically the average values of the results for all experimental years. And in the three experimental years an increase in productivity is observed by increasing the pre-irrigation soil moisture. Averaged data show that by maintaining pre-irrigation humidity over 60% of FC, from 1 mm irrigation water an additional yield of 12 kg/ha is received, at 70% of FC – about 20 kg/ha. The highest productivity is observed at irrigation rate 80% of FC. In this variant it is 4 times greater than the second variant. Higher pre-irrigation humidity (90% of FC) leads to lower productivity of the irrigation rate by 17% on average, as the provided larger irrigation rate does not increase the yield.

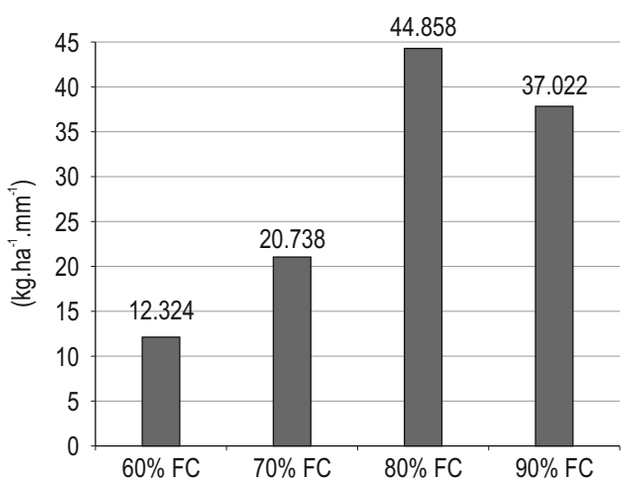

Figure 3. Irrigation depth productivity depending on pre-irrigation soil moisture (average for 2010 – 2012)

Conclusions

The yield of green beans grown at non-irrigated conditions in the region of Plovdiv varies from 1144 kg/ha in dry years to 8393 kg/ha in medium wet years.

Maintaining pre-irrigation soil moisture over 80% of FC increases and stabilizes the yield substantially, as it increases by 80–90% in medium wet years to more than 5 times in extremely dry years. They are in the range from 12 to 16 t/ha

By maintaining soil moisture over 90% of FC the yield was comparable to that in the maintenance of 80% of FC, at the same time the productivity of the irrigation rate is reduced by 17% on average. Therefore, this irrigation regime is not recommended for use in practice.

Irrigation by 70% of FC is not recommended during dry and extreme years as the yield will be decreased by 82%. In medium wet

years with shortage of irrigation water its application may be allowed and the yield is 64% of the maximum.

The highest is the productivity of irrigation rate by maintaining 80% of FC, as from 1 mm irrigation water an additional yield with an average amount of 45 kg/ha is obtained.

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Instruction for authors

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The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods,Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

Names and affiliation of authors The names of the authors should be presented from the initials of first names followed by the family names. The complete address and name of the institution should be stated next. The affiliation of authors are designated by different signs. For the author who is going to be corresponding by the editorial board and readers, an E-mail address and telephone number should be presented as footnote on the first page. Corresponding author is indicated with *.

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The introduction must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal ?

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Oldenbroek JK, 1999. Genebanks and the conservation of farm animal genetic resources, Second edition. DLO Institute for Animal Science and Health, Netherlands.

Book chapter or conference proceedings: Author(s) surname and initials, year. Title. In: Title of the book or of the proceedings followed by the editor(s), volume, pages. Name of publisher, place of publication. Example:

Mauff G, Pulverer G, Operkuch W, Hummel K and Hidden C, 1995. C3-variants and diverse phenotypes of unconverted and converted C3. In: Provides of the Biological Fluids (ed. H. Peters), vol. 22, 143-165, Pergamon Press. Oxford, UK.

Todorov N and Mitev J, 1995. Effect of level of feeding during dry period, and body condition score on reproductive performance in dairy cows,IXth International Conference on Production Diseases in Farm Animals, Sept.11 – 14, Berlin, Germany, p. 302 (Abstr.).

Thesis:

Penkov D, 2008. Estimation of metabolic energy and true digestibility of amino acids of some feeds in experiments with muscus duck (Carina moshata, L). Thesis for DSc. Agrarian University, Plovdiv, 314 pp.

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Studies performed on experimental animals should be carried out according to internationally recognized guidelines for animal welfare. That should be clearly described in the respective section “Material and methods”.

AGRICULTURAL SCIENCE AND TECHNOLOGY

Volume 5, Number 4
December 2013

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