ESTIMATION OF THE COMPETITIVE RELATIONS AND THE INDIVIDUAL PRODUCTIVITY OF FIELD BEANS IN MODEL EXPERIMENTS

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Abstract

The investigation of the competitive relationship between the plants of field beans was carried out in a model experiment, the scheme of which included sowing by the ray-stretching method. The offered method of plant location which takes into account the peculiarities of modern intensive varieties of crops enables the researcher to evaluate a great number of densities from 2061 to 269 thousand plants per hectar, inter-row width from 10 to 77 cm and areas of nutrition from 48 to 386 cm^2 in a wide diapason and to describe their competitive relations. This approach can be used when carrying out similar experiments with other grain-legume and fodder crops. It has been determined that the increase of nutrition the area and inter-row width and the reduction of plant density results in the increase of plant weight, thickness of the stem base, quantity of productive nodes, beans, seed weight per plant and the weight of 1000 seeds. It has been established that the character of the change of these indices is rectilinear. But plant height, the height of the bottom bean location, quantity of nodes on a plant and the level of grain productivity have a parabolic character. It will be shownthat under conditions of Forest-Steppe on grey forest soils there is a certain interval of the nutrition area, inter-row width and plant density which facilitates the increase of the grain productivity of field beans. The highest grain productivity of field beans of the variety Orion is formed in the nutrition area from 176 to 278 cm^2 with inter-row width 33-35 cm and plant density 596-359 thousand per hectar. Further increase or reduction of the nutrition area, inter-row width and plant density results in changes of the elements of individual productivity of field bean plants towards reduction which has a negative influence on the formation of grain yield formation per unit of area.

Key words

Competitive relations, individual productivity, field beans, model experiments.

Introduction

The process of the formation of high productive field beans is expected to meet all biological needs of certain varieties for heat, light, nutrition, moisture and gas regime due to optimization of technological techniques of their growing. This is especially typical for the right-bank Forest-Steppe of Ukraine where moisture can be a limiting factor for field beans. Field beans as water-resistant plants have a great variability of certain the productivity depending on species on growing conditions, so, they extensively react to changes in the nutrition area and the methods of plant location in agrobiocenose. As a result the, manifestation of competitive relationships and possible density intervals between the plants in field bean agrobiocenose, in order to reveal the mechanism responsible for plant reaction within the limits of the determined intervals of their density as well as the study of the possible biological potential for individual productivity formation, have become an important scientific problem and require the theoretical substantiation of the growing technology models taking into account characteristics of soil and climatic conditions of the regions of Ukraine.

Materials and Methods

Research into the competitive relationship between field bean plants was carried out in model trials during 1998-2006 in the Feed Research Institute of the UAAS. Soils were grey forest mid-loams**;** their topsoil contained: humus (by Tyurin) – 2,1-2,3 %, easily hydrolyzed nitrogen (by Cornfield) – 90-112 mg per 1 kg of soil, labile phosphorus and exchange potassium (by Chirikov) correspondingly 121-142 and 81-116 mg per 1 kg of soil, pH (salt) – 5,2-5,4, level of soil base saturation – 85,7-87,3 %. Mid-ripe field bean variety Orion was sown in the trial. Its vegetation period is 98-101 day. The variety is resistant to diseases, bean cracking and lodging.

On the basis of the research carried out on soybean and field beans by the scientists A.O. Babych and V.F. Petrychenko (Babych A.O., Petrychenko V.F., 1994) modification of the system model J.A. Nedler (Nedler J.A., 1962), described by W.G. Duncan (Duncan W.G., 1986) and D.B. Egli (Egli D.B., 1988), which requires planting by the ray-stretching method, was offered. Taking into consideration the ability of the new varieties selected in Ukraine to increase productivity when there is constricting row-space, optimizing mineral nutrition and enlarging plant density per unit of area, the trial was organized in a way to enable the nutrition area of a plant to increase gradually while removing it from the center of the circle. Such a method enables the researcher to evaluate a great number of densities of field bean varieties which are widely studied on comparatively small trial plots.

To avoid the harmful influence of the first plants on one other from the neighbour rays which come from the circle center and create identical conditions for plants studied in variants as well as increase reliability of the obtained trial results, one more circle with the diameter equaling the width of the basic row-spacing in existing growing technologies in the region was made in the centre of a big circle. In our researches the width of row-spacing was 45 cm. It should be mentioned that ray quantity depends on the group of variety ripeness. The circle should be divided into 32 or 64 rays for early- and mid-ripe varieties, and into 16 and 32 rays for late-ripe ones. Model trials on field beans included 32 rays. Each plant presented a separate variant. Repetition of the trial equaled 32. Plants with the distance between the rays of 45 cm were taken for control. The distance between the plants in a ray was 5 cm (fig. 1).

When it is necessary to study the reaction of some varieties to space and quantitative plant location in the area, the circle is divided into 2 or 4 sectors, i.e. 16 or 8 rays in each one. It let plants function as protection strips. Biometric research is carried out on plants located in the internal rays of the sector.

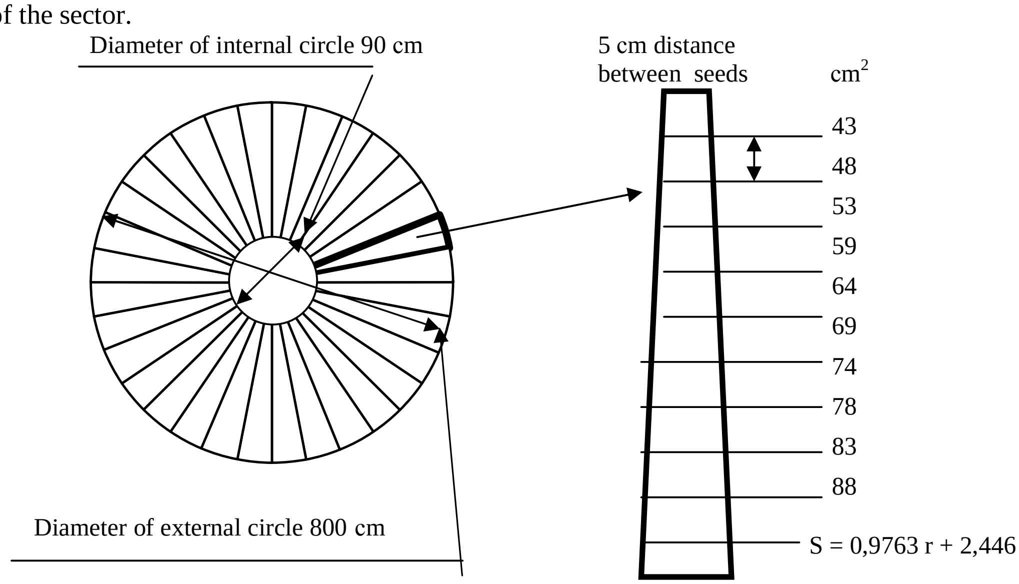

Figure 1. Scheme of plant location in the model trial and the area of their nutrition

Results and Discussion

The use of the system method of trial result evaluation shows that the change of the nutrition area of plants and, therefore, plant density results in the formation of different structures and influences the individual productivity of the crop.

The research reveals that the increase of the nutrition area and interrow width as well as the reduction of plant density per unit of area facilitates the increase of seed weight, the thickness of the stem base, the quantity of productive nodes, beans, seeds, seed weight per plant and the weight of 1000 seeds. These changes are rectilinear. But plant height, the height of the bottom node location, the quantity of nodes per plant and the level of yield capacity has a parabolic character, i.e. these indices increased the margin of the nutrition area, interrow width and plant density. Further increase of the nutrition area and interrow width and the reduction of plant density counting the unit of the area did not provide an increase of the indices of the structure and yield capacity of field beans, but their gradual reduction (fig.2).

Thus, when increasing the nutrition area from 48 to 303 cm^2, and the interrow width from 10 to 75 cm and reducing the plant density from 2016 to 266 thousands per hectar plant weight increased from 5,8 to 42,5 g, the thickness of the stem base – from 0,4 ro 1,65 cm, the quantity of productive nodes per plant – from 2,9 to 9,5 units., beans – from 3,2 to 10,8 units, seeds – from 7,2 to 27,0 units., seed weight per plant – from 1,2 to 12,4 g (table 1, 2).

Dependence of field bean plant weight on the nutrition area, interrow width and plant density can be presented by the following regression model:

$$У_1 = - 81,1791 – 2,1245X_1 + 16,1903X_2 + 1,1574X_3$$

where,
$У_1$ – plant weight, g
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm

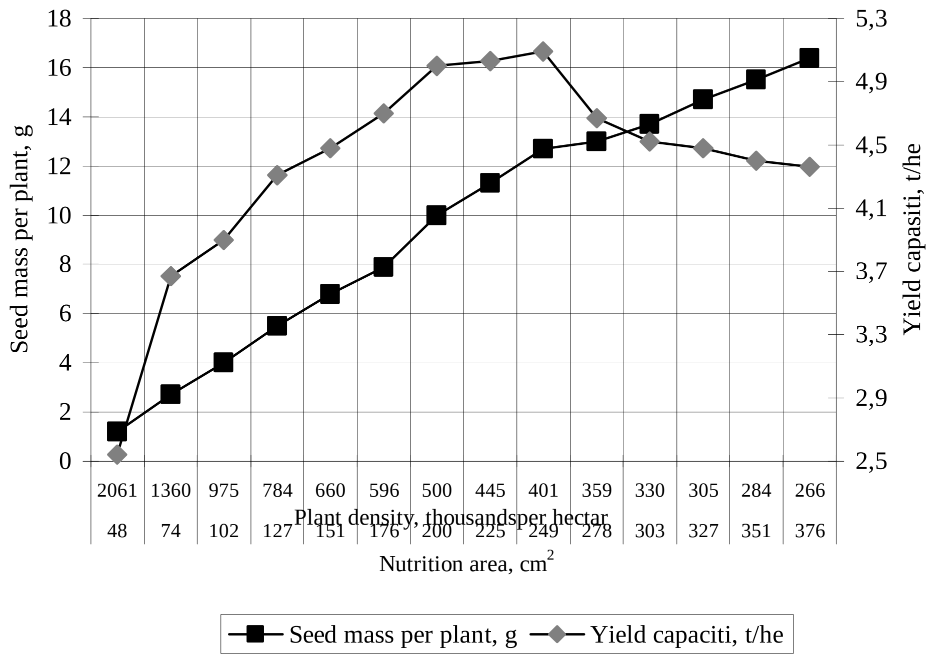

Figure 2 The characteristics of the changes of individual field beans and the grain productivity of field beans depending on the influence of space and quantitative plant location

A strong positive connection is observed between the plant weight and the nutrition area, interrow width and plant density. The coefficient of multiple correlations equals 0,966. It is established that field beans are inclined to lodging when the thcknessof the stem base is reduced up to 0,63 cm. As a rule this is an interval of the nutrition area 48 to 127 cm^2, interrow width from 10 to 25 cm, plant density from 2061 to 784 thousands per hectar.

Dependence of node quantity per plant on the nutrition area, interrow width and plant density is described by the equation of multiple regression:

$$У_2 = - 17,1126 + 1,1748X_1 - 0,1304X_2 + 0,2769X_3$$

where,
$У_2$ – quantity of productive nodes, units.
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm

A strong positive connection is observed between the quantity of productive nodes and factors studies in the model trial (r = 0,988).

Table 1. The formation of the indices of field bean structure depending on the influence of space and quantitative plant location (in average in 1998-2006)

Nutrition area, cm^2	Interrow width, cm	Plant density, thousands per hectar	Plant weight, g	Plant height, cm	Height of the bottom bean location, cm	Thickness of the stem base, cm
48	10	2061	5,8	80,5	49,8	0,40
74	15	1360	7,3	82,9	46,7	0,45
102	20	975	8,6	84,2	46,4	0,52
127	25	784	10,2	86,4	46,0	0,63
151	30	660	12,1	88,6	44,9	0,75
176	35	596	12,5	90,9	43,5	0,78
200	40	500	16,8	91,7	43,0	0,86
225	45	445	20,3	92,2	43,0	0,93
249	50	401	21,5	93,5	43,0	1,00
278	55	359	22,0	85,3	40,5	1,15
303	60	330	23,1	87,0	38,6	1,27
327	65	305	25,9	82,2	38,3	1,35
351	70	284	35,5	81,8	38,0	1,57
376	75	266	42,5	80,9	31,8	1,65

Dependence of bean quantity per plant on the nutrition area, interrow width and plant density is described by the equation of multiple regression:

$$У_3 = - 5,2077 + 0,3121X_1 + 1,1103X_2 + 0,0542X_3$$

$У_3$ – quantity of beans, units
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm.

For effective index $У_3$ coefficient of multiple correlation equals 0,993. It testifies to a close positive connection.

The size of the nutrition area, interrow width and plant density also influence the seed quantity per plant and the weight of these seeds. Revealed dependences are described by the following equations of multiple regression:

$$У_4 = - 19,1209 + 1,4842X_1 + 1,7387X_2 + 0,2229X_3$$

$У_4$ – seed quantity per plant, units.
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm
$У_5 = - 13,0450 + 0,8093X_1 + 1,4746X_2 + 0,0828X_3$
$У_5$ – seed weight per plant, g
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm

For effective indices $У_4$ and $У_5$ coefficients of multiple correlation equal 0,994 and 0,997 correspondingly.

Table 2. The formation of the indices of individual productivity of field bean plants depending on the influence of space and quantitative plant (in average in 1998-2006)

Nutrition area, cm^2	Interrow width, cm	Plant density, thousands per hectar	In average on a plant, units.				Seed weight per plant, g	Weight of 1000 seeds, g	Yield, t/he
			nodes	Productive nodes	beans	seeds			
48	10	2061	18,4	2,9	3,2	7,2	1,2	170	2,54
74	15	1360	18,6	3,0	3,7	8,7	2,7	310	3,67
102	20	975	18,7	3,3	3,9	9,8	4,0	408	3,90
127	25	784	20,3	3,4	5,1	11,8	5,5	466	4,31
151	30	660	20,6	3,7	6,2	14,4	6,8	472	4,48
176	35	596	21,0	3,9	7,0	15,5	7,9	509	4,70
200	40	500	22,1	4,5	8,0	18,1	10,0	552	5,00
225	45	445	22,9	5,3	8,2	20,4	11,3	553	5,03
249	50	401	25,1	6,0	9,1	22,7	12,7	561	5,09
278	55	359	23,8	7,0	9,2	23,0	13,0	565	4,67
303	60	330	22,7	7,7	9,6	24,1	13,7	568	4,52
327	65	305	22,4	7,8	10,2	25,5	14,7	578	4,48
351	70	284	22,6	8,1	10,7	26,5	15,5	584	4,40
376	75	266	22,6	9,5	11,0	27,3	16,4	600	4,36

Dependence of the weight of 100 seeds on the quantitative and space location of plants in the area is described by the equation of multiple regression:

$$У_6 = 1145{,}9452 – 22{,}4016X_1 + 23{,}3250X_2 – 19{,}7489X_3$$

$У_6$ – weight of 1000 seeds, g
X_1 – nutrition area, cm^2
X_2 - plant density, thousands per hectar
X_3 – interrow width, cm

A very positive connection between the weight of 1000 seeds and the nutrition area, interrow width and plant density is revealed. The coefficient of multiple correlation equals 0,997.

It should be mentioned that seed productivity of field beans in re-calculation for a unit of area increase from 2,54 to 5,0 t/he when the nutrition area was increased from 48 to 200 cm^2, which corresponds to the interval of the interrow width from 10 to 40 cm and plant density from 2061 to 500 thousands per hectar. Further changes in the nutrition area, interrow width and plant density resulted the of yield capacity staying at almost the same level 5,03-5,09 t/he. There was a reduction of the level of field bean grain yield from 4,67 to 4,36 t/he. Analogical dependence was demonstraled in the trials with soybean (Babych A.O., Petrychenko V.F., 1995; Babych A.O., Petrychenko V.F *et.al.* 1998).

Conclusion

Thus, the high plasticity of the field bean variety Orion to changes in the nutrition area, interrow width and plant density was determined. In other words, there is a certain interval of the nutrition area, interrow width and plant density which facilitates the increase of grain productivity of field bean plants. The highest grain yield of field bean variety Orion (5,03-5,09 t/he) is formed when the nutrition area is 176 to 278 cm^2 with interrow width 35-55 cm and plant density 596-359 thousands per hectar, maximum (5,09 t/he) – when nutrition area is 249 cm^2, with plant density 401 thousands per hectar and interrow width 50 cm. Further increase or reduction of the nutrition area, interrow width and plant density results in changes in the individual productivity of field bean plants towards reduction with a negative influence on the level of grain yield per unit of area.

So, the formation of a rational optical-biological structure for field bean sowings is growing in importance as it is one of the determining factors when studying and evaluating the models of bean field sowing growing technology.

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PHOTOSYNTHETIC RADIATION USE EFFICIENCY OF DIFFERENT OAT CULTIVARS UNDER DIFFERENTIATED NITROGEN FERTILIZATION

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Abstract

In a field experiment conducted with two oat's morphotypes (hulled and naked), fertilized with differentiated nitrogen rates (0, 30, 60, 90 and 120 kg N ha^{-1} the biomass production of plants in canopy was evaluated using indices of energetic analysis, coefficient of radiation use efficiency (RUE) by the plants in the canopy among others. It was found the hulled oat's morphotype characterizes with bigger degree of transformation radiant energy into biomass as compared to the naked one (on average for whole experiment the energy yield for cv. Chwat was 15.0 while fot cv. Akt 13.6 MJ m^{-2}. Maximum transformation of radiant energy into biomass was found for traditional morphotype at 90 kg N ha^{-1}, while for naked one already at 30 kg N ha^{-1}, (respectively). Radiation use efficiency (RUE) for grain production was bigger in cv. Chwat as compared to cv. Akt, being 2.77 and 1.49 g d.m. MJ^{-1}, respectively. RUE for biomass production also was bigger in hulled morphotype, being 3.36 *vs* 3.20 g d.m. MJ^{-1} in naked one. The rate 90 kg N ha^{-1} for cv. Chwat and 30 kg N-ha^{-1} for cv. Akt seem to be physiologically optimal.

Key words

Nitrogen, fertilization, oat, PAR, solar radiation, RUE

Introduction

According to the model elaborated by Monteith (1977) there is a possibility to present biomass production as a linear function of photosynthetic active radiation (PAR, wavelength 400-700 nm) intercepted by a canopy. Varlet-Grancher *et al.* (1993) improved this semi-empiric model of dry matter accumulation in canopy, by relating PAR to energy yield of crop. The basic component of both models is a concept of radiation use efficiency (RUE), being the ratio of total biomass produced and unit of PAR intercepted by the canopy (Faber, 2000). RUE is also principal