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## PRODUCTIVITY OF A SANDY RYEFIELD*

(Ekol. Pol. 21: 339–357). Studies were made in 1969 and 1970 of the total production of vascular plants in a ryefield in the southern part of the Wielkopolska region of Poland.

Rye and weed production was defined on the basis of samples taken at the time of maximum development of the plants, and this evaluation was supplemented by an estimate of the biomass of sterile shoots which died during the development of the rye.

While total primary production was approximately equal in the two study years (ranging from 1007 to 1159 g/m$^2$), considerable differences were found in the production of sterile shoots and also of rye grain.

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## 1. INTRODUCTION AND STUDY AREA

The studies presented here on primary production of a ryefield form an integral part of the research undertaken by the Agroecological Station of Polish Academy of Science in Turew on the energy flow and matter circulation in the ecosystems of cultivated fields. Although the primary production of these fields was already estimated by Herbich (1969), we still need, every year, new current data on the production value of the first link in the food chain of the fields in which these group ecological studies are concentrated.

The study area consisted of cultivated fields belonging to the Plant Breeding Station at Rogaczewo (administrative district Kościan, Poznań voivodship) adjoining a wide shelter belt forming an avenue running north to south. In 1969 the ryefield was situated to the west of the shelter belt, in 1970 to the east.

The soil of the two fields (Kutera 1956) was light and sandy, with a poorly formed humus horizon up to a depth of 30 cm. The soil is highly permeable, with poor water retention, because of the preponderance of the sandy fraction in its mechanical composition.

In both fields the soil comes within class I in respect of assimilable potassium and phosphorus (15.5–27.5 mg $K_2O$/100 g of soil, 10.6–50 mg $P_2O_5$/1 g of soil). The same is true about calcium. Active acidity of the superficial layers of soil defined in $H_2O$ was 7.40–8.70 in the field on the west and 5.9–7.20 in the field on the east. Hydrolytic acidity was 0.25–0.35 and 1.2–3.1 ml 0.1 n NaOH/100 g of soil, respectively.

The segetal plant communities developing in the grain crops in these sandy soils, which are relatively rich, low in acidity and rapidly drying in spring, belong to the *Papaveretum argemones* association characterized by a spectacular spring aspect off weeds (Tab. I). It is a wellknown fact that there is a distinct connection between a field plant association defined on the basis of characteristic species of weeds and the crop yield of cultivated plants (Walther 1953 and 1954). There can thus be no doubt that in time, it will be possible, to grasp the connection between the plant association and the value of the total plant production of a field.

The weather in the two study years differed, particularly in respect of rainfall during the growing season (Tab. II). In 1969 there was a severe drought in July (10.6 mm rainfall as compared with the long-term average for July of 66.7 mm), combined with average high temperature (20.0°C). This had no harmful effect at all on the rye crops, which had by then ripened and dried. In 1970, on the other hand, there was very heavy rainfall in April when the rye was tillering (66.8 mm as compared with long-term average of 38.9 mm). There was, however, a drought by June (26.9 mm as compared with long-term average of 56.4) with a high temperature of 18°C. This type of weather was unfavourable

Plant community of the ryefield

Tab. I

| Section of the field | *A* | *B* | *C* | *D* |
|---|---|---|---|---|
| Cover of the rye stand | 80 | 80 | 80 | 80 |
| Cover of the field weeds | 30 | 20 | 15 | 30 |
| Date of the record | 17 VI 70 | 17 VI 70 | 17 VI 70 | 9 VII 70 |
| *Apera spica venti* | 3.1 | 2.1 | 2.1 | 3.1 |
| *Polygonum tomentosum incanum* | 1.1 | 1.1 | 1.1 | + |
| *Vicia angustifolia* | • | + | 1.1 | 1.1 |
| *V. hirsuta* | • | + | 1.1 | • |
| *Centaurea cyanus* | • | 1.1 | + | • |
| *V. tetrasperma* | • | • | 1.1 | • |
| *Lithospermum arvense* | • | • | 1.1 | • |
| *Viola arvensis* | 1.1 | 1.1 | 1.1 | 1.1 |
| *Polygonum convolvulus* | 1°1 | +° | +° | 1.1 |
| *Thlaspi arvense* | + | + | + | + |
| *Veronica arvensis* | + | • | + | + |
| *Myosotis arvensis* | • | + | 1.1 | 2.1 |
| *Anagalis arvensis* | • | + | + | 1.1 |
| *Anthemis arvensis* | • | + | + | • |
| *Lycopsis arvensis* | • | • | + | + |
| *Sonchus arvensis* | • | • | + | + |
| *S. asper* | • | • | • | 1.1 |
| *Stellaria media* | 2.1 | 1.1 | 2.1 | 1.1 |
| *Geranium pusillum* | + | + | + | + |
| *Agropyron repens* | 1.1 | 2.1 | 1.1 | 2.1 |
| *Capsella bursa pastoris* | + | • | + | + |
| *Chenopodium album* | +° | 1°1 | • | +° |
| *Cirsium arvense* | • | 2.1 | 1.1 | 2.1 |
| *Equisetum arvense* | • | + | + | 1.1 |
| *Poa annua* | 1.1 | • | + | • |
| *Descurainia sophia* | • | • | +° | • |
| *Melandrium album* | 1.1 | • | + | 1.1 |
| *Crepis tectorum* | + | + | + | • |
| *Medicago lupulina* | • | + | + | + |
| *Arenaria serpyllifolia* | • | • | 1.1 | 1.1 |
| *Viola tricolor* | • | • | + | • |
| *Cerastium semidecandrum* | • | • | + | • |
| *Polygonum persicaria* | • | • | • | + |
| Vernal aspect of the field 5 V 1969 | | | | |
| *Veronica triphyllos* | 3.1 | 3.1 | 4.1 | 4.1 |
| *V. hederifolia* | 3.1 | 3.1 | 4.1 | 4.1 |
| *Lamium amplexicaule* | 1.1 | 2.1 | 1.1 | 1.1 |
| *Arabidopsis thaliana* | + | + | + | + |
| *Erophila verna* | + | + | + | + |
| *Stellaria media* | 3.2 | 3.2 | 3.2 | 3.2 |
| *Holosteum umbellatum* | • | + | + | • |

Meteorological data for Rogaczewo

Tab. II

| Month | Mean monthly temperatures | | | Total monthly precipitation | | |
|---|---|---|---|---|---|---|
| | 1968/1969 | 1969/1970 | 1953/1970 | 1968/1969 | 1969/1970 | 1953/1970 |
| X | 9.3 | 9.3 | | 40.7 | 14.2 | |
| XI | 4.3 | 5.3 | | 56.1 | 36.4 | |
| XII | -2.9 | -7.8 | | 29.9 | 12.4 | |
| I | -4.1 | -6.2 | | 46.6 | 38.1 | |
| II | -2.9 | -3.6 | | 24.9 | 33.3 | |
| III | -1.0 | 0.0 | | 32.1 | 33.0 | |
| IV | 7.3 | 6.6 | 8.0 | 42.8 | 66.8 | 38.9 |
| V | 14.2 | 12.4 | 13.0 | 38.3 | 47.7 | 55.0 |
| VI | 17.2 | 18.0 | 17.1 | 44.7 | 26.9 | 56.4 |
| VII | 20.0 | 18.2 | 18.8 | 10.6 | 46.2 | 66.7 |
| VIII | 17.3 | 18.3 | 17.8 | 100.4 | 46.4 | 68.6 |
| IX | 14.7 | 13.5 | 14.5 | 9.2 | 53.2 | 41.1 |
| Mean temperatures and total precipitation for year | 7.8 | 7.0 | | 476.3 | 454.6 | |

to rye crops, especially as in 1970, the plants did not begin to grow intensively until late owing to the snow cover lying far longer than usual.

Since 1958, two-field rotation of crops had been constantly maintained, rye and potatoes being alternately grown on the fields. It was only in 1965 that potatoes were grown on both sides of the shelterbelt. During the study years, normal cultivation operations were carried out in the fields, including heavy mineral fertilization which was very slightly increased in 1970. In pure components this consisted of:

in 1969 $P_2O_5$ – 57.6, $K_2O$ – 92 and N – 65.5 kg/ha
in 1970 $P_2O_5$ – 72.9, $K_2O$ – 120 and N – 71.5 kg/ha

As only two-field rotation of crops was employed each rye crop was grown the year directly following fertilization with manure (150 and 250 kg/ha).

Rye was sown late: in 1969 on September 28th, and in 1970 on October 12th, as potatoes were not lifted from the field until the end of September. The "Włoszanowskie" variety of rye, suited to dry conditions, was sown in amounts of 135 kg of grain per hectare.

## 2. RESEARCH METHODS AND PROCEDURE

In choosing the study method the following matters were taken into consideration:

a. the need to grasp as far as possible all the component elements of primary production in the field over the period of a year (from the beginning of October to the end of September). In our studies these were: upper and underground parts of rye plants, upper and underground parts of weeds and self-sown aftercrop of rye and weeds which are ploughed in autumn;

b. the need for ensuring that plants or parts of plants which died before the cultivated crop became fully ripe are not omitted from the estimate;

c. the need to grasp differences in primary production over the whole of a large field in which habitat conditions were not uniform, for instance on account of the vicinity of the shelter belt;

d. the need to make an estimate of primary production quickly and easily, so that in case of need it would be possible to repeat this kind of estimate several times at different times and places;

e. the need to ensure that the least damage possible was done to the cultivated plants.

Estimates of the most important component of field production, i.e. the upper parts of rye plants, were made principally by the harvest method at the time the rye attained full development. Samples taken directly before harvest consisted of ripe rye together with the summer weeds growing among it.

Rye tillers fairly abundantly, but not all shoots growing from the grain form culms and, eventually, ears. Part of them die sterile and are not included in the crop harvested. Consequently, they were not included in our basic samples. Therefore, estimate of corn production based on samples obtained by the harvesting method at the time rye attained full development was supplemented by an estimate of the biomass of sterile shoots dying before the grain ripened.

The technique of estimating the biomass of sterile shoots was based on Traczyk's method (1967) for estimating production of upper parts of forest herb layers. This method consisted in estimating the average individual growth of species at the time they attain full development and their average density in the study area, and then calculating primary production by multiplying these two values. This method was adapted for evaluating the relations in the rye field.

Unlike the original method, the density and biomass of rye shoots was estimated twice; first in spring, at time of their maximum density, and second, immediately after harvesting. The difference between these densities was used to define the number of shoots that died out before rye ripened. This value, multiplied by the average biomass of a shoot in spring, gave the value of organic matter produced in the field, but not included in the basic sample. This way, it was possible to take into account the greater part of dead organic matter, although dying leaves and shoots were not collected over the whole growing season. The procedure used in these studies was thus as follows:

## 2.1. Rye

### 2.1.1. Upper parts

In spring, at the moment of shooting out, i.e. after the rye had tillered and developed the maximum number of shoots, an estimate was made of the density of rye shoots and biomass of an average shoot.

Density was estimated in situ by throwing a hoop 300 $cm^2$ in area on the field of rye, repeatedly, at different distances from the shelter belt and taking everything it contained as a sample (Tab. III).

The biomass of an average shoot was estimated in 1969 on two transects running across the field from the shelter belt to the centre; 100 plants were taken from each transect. The mass of 200 tillered rye plants was divided by the number of single shoots contained in this sample, and result gave the average biomass of one shoot. In 1970, considerable differences in the development of rye were observed within the field. In addition to shoot density per unit of area of the field, the percentage of well developed green shoots in the crop, and the percentage of weak yellow shoots in each sector of the field were defined; two individual biomasses were also estimated.

When the rye was fully ripe before the harvest an estimate was made of the biomass of the upper parts of plants, taking samples by the harvesting method, and cutting the stalks as close to the soil as possible.

First thing after reaping the corn, its density in the stubble was assessed immediately behind the harvester in the same way as in spring.

The difference between densities of young shoots when most numerous in spring and the densities of culms cut during harvesting gave the number of shoots which failed to develop into culms and died before the rye ripened.

The number of dead shoots was multiplied by the individual biomasses of shoots defined in spring. The biomass values obtained in this way were added to the values of biomasses defined on the basis of samples taken at the moment of full development of the rye. The results obtained were amended by adding a small correction for the mass of bases of culms collected with root systems but belonging to the upper parts of plants.

In the harvested crop, the percentage of culms with ears fully formed, that on culms with ears not fully formed and the dry mass of grain, was defined on the basis of samples taken before harvesting.

### 2.1.2. Underground parts of rye plants

The biomass of rye roots was estimated together with roots of weeds having a similar development period to that of rye (summer weeds). Samples 20 x 20 cm. in area were taken from the plough layer (up to depth of 30 cm.). In 1969, roots were sifted dry but in 1970 were washed with water. Calculation was made of total biomass of roots formed in the field; for roots growing deeper 8% were added to the values obtained from sifting the plough layer (Herbich 1969). Average figures from all the samples taken were accepted as root biomasses in sectors from which no samples were taken. Root biomasses of rye and weeds were calculated, with assumption that they are in proportion to those of the upper parts of the plants.

## 2.2. Weeds

Biomass of weeds was estimated in two throws:

1. Spring weeds, small therophytes growing between rows, producing seed and dying before the harvest, were picked up together with their shallow root systems and weighed after drying.

2. Summer weeds, with a development period similar to cereals, and with deep root systems, were estimated on the basis of the same samples as rye. The upper parts of these weeds collected with the upper parts of rye were separated in order to dry and weigh them separately. Their root systems, on account of technical difficulties in separating them, were dried and weighed together with rye, and thus the number of samples and times of their collection were the same as for rye.

## 2.3. Self-sown after-crop of rye and weeds

After the rye had been harvested self-sown rye from grain spilt during harvesting, and small weeds which are usually destroyed during autumn ploughing, appeared on the field. The organic matter thus produced was assessed from samples taken immediately before the field was ploughed.

The whole of the plant material taken for assessing biomass was dried to a constant weight at a temperature of 85°C and weighed with accuracy to 0,05 g.

Only the production of the vascular plants in the field was thus investigated, no mosses or liverworts being found in the study fields. Very slight appearance of greeny algae found here and there in the depressions in the stubble field after rain was not taken into account.

Samples numbers and sizes

| Fields section | Distance from shelter-belt in m | Year 1968/1969 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | rye | | | | | weeds | | |
| | | density | | biomass | | roots | vernal | aestival | |
| | | 5–7.5. | 5–8.7. | 7.5. | 18–19.7 | 21–23.7 | 4–5.5. | 19.7. | |
| *A* | 0–10 | 30 | 30 | 10 | 30 | 3 | 10 | 30 | |
| *B* | 10–50 | 50 | 100 | 40 | 29 | – | 10 | 30 | |
| *C* | 50–100 | 50 | 100 | 50 | 31 | 3 | 10 | 29 | |
| *D* | 100–150 | 50 | 100 | 50 | 30 | – | 10 | 30 | |
| *E* | 150–200 | 50 | 100 | 50 | 30 | 3 | – | 30 | |
| Total field | 0–200 | 230 | 430 | 200 | 150 | 9 | 40 | 149 | |
| Kind of sample | | circle 300 $m^2$ | circle 300 $m^2$ | 1 plant= 4 shoots | circle= 300 $cm^2$ | square 400 $cm^2$ x 30 cm | circle 1000 $cm^2$ | circle 300 $cm^2$ | |

## 3. RESULTS

### 3.1. Primary production of the rye field as a whole

All the component elements of plant biomass obtained from field samples, and from preliminary calculations are listed in Table IV. The final results of the estimate of primary production in the field are shown in Table V.

It can be seen from these tables that the combined primary production of vascular plants in the ryefield in both study years is nearly 1 kg dry mass/1 $m^2$ (in 1969 – 1159, and in 1970 – 1007 g dry mass).

These values for ryefield production are almost identical with the values obtained for by Köhnlein and Vetter at Schädtbek in West Germany (after Lieth 1962), who estimated rye production in 1953 as 1002 g of dry mass/$m^2$.

In this mass of organic matter the greater part consists of the upper parts of rye plants 76% in 1969 and 79% in 1970.

The roots of rye and summer weeds in our fields formed almost 16% of the whole organic matter produced by these two greatest components of field production, and over 18% of the mass of their upper parts. This last relation is very important on account of the possibility of calculating root mass on the basis of the easily measured mass of upper parts. In our case, it is very similar to the values in the studies made by Herbich (1969), who gives a figure of 16.5% for both study years. The values for ratio of root mass to mass of upper parts and sampling date

Tab. III

| Year 1969/1970 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| self-sown aftercrop | rye | | | | | weeds | | self-sown aftercrop |
| | density | | biomass | | roots | vernal | aestival | |
| 5.9. | 12–14.5 | 15–18.8. | 14.5. | 11.8. | 30.6 | 25–26.5. | 11.8 | 26.10 |
| 30 | 20 | 20 | | 6 | 2 | 10 | 6 | 3 |
| 30 | 80 | 80 | | 24 | | 40 | 24 | 15 |
| 30 | 100 | 100 | | 30 | 2 | 50 | 30 | 15 |
| 30 | 100 | 100 | | 30 | | 50 | 30 | 15 |
| 30 | 100 | 100 | | 30 | 2 | 50 | 30 | 15 |
| 150 | 400 | 400 | 400 | 120 | 6 | 200 | 120 | 63 |
| circle 300 $cm^2$ | circle 300 $cm^2$ | circle 300 $cm^2$ | 1 shoot | circle 1000 $cm^2$ | square 400 $cm^2$ x 30 cm | circle 300 $cm^2$ | circle 1000 $cm^2$ | circle 300 $cm^2$ |

obtained in these fields both by us and by Herbich come between the values of this relation given for rye in Germany: 13,73% and 27,75% (Köhnlein and Vetter after Lieth 1962) and 22% (Lieth after Bray 1963), but our results differ markedly from those of Bray, Lawrance and Pearson obtained for dry areas in Arizona (U.S.A.) where this ratio is 269%, with a combined production for rye and weeds very similar to ours (960 g dry mass/$m^2$).

The percentage of weeds in the primary production of a field was 7.5% in 1969, and 3.4% in 1970. It was calculated on the assumption that the ratio of root mass of weeds to roots of rye is equal to the ratio of their upper parts. Together with the sprouting plants on the stubblefield this formed 10 and 6.5% of the combined production of the field, respectively.

Spring weeds and self-sown rye on the stubblefield are the two elements in the ryefield production not taken into account by Herbich. Their participation in combined production of the field was as follows: spring weeds 1 and 1%, and aftercrop of rye and weeds 3 and 2.8% for two years under consideration.

### 3.2. Primary production of the field at different distances from shelterbelt

When we consider combined primary production in different sectors, ranged according to their increasing distance from the shelterbelt, we see that the

Primary production of rye fields
The elements evaluated from samples

| | Fields section | Above-ground parts of rye: dead veget. shoots | stalks with leaves | bases of stalks | grain | total | Roots of weeds to 10 cm |
|---|---|---|---|---|---|---|---|
| West field, 1969 | *A* | 172.20 | 419.97 | 7.50 | 163.70 | 763.37 | – |
| | *B* | 58.59 | 602.33 | *14.77* | 272.00 | 947.69 | – |
| | *C* | 88.83 | 509.00 | 13.25 | 254.00 | 865.08 | – |
| | *D* | 66.15 | 593.66 | *14.77* | 283.00 | 957.58 | – |
| | *E* | 46.20 | 499.00 | 17.75 | 245.00 | 807.95 | – |
| | Average | 70.62 | 541.88 | 14.77 | 258.09 | 885.36 | – |
| East field, 1970 | *A* | 90.73 | 354.80 | 10.50 | 164.80 | 620.83 | 53.00 |
| | *B* | 147.41 | 369.80 | *10.16* | 174.62 | 701.99 | |
| | *C* | 127.82 | 426.90 | 8.75 | 220.88 | 784.35 | 96.00 |
| | *D* | 138.33 | 470.00 | *10.16* | 224.42 | 842.91 | |
| | *E* | 133.33 | 476.50 | 11.50 | 225.97 | 847.30 | 75.00 |
| | Average | 133.89 | 435.05 | 10.16 | 210.98 | 790.08 | |

production in the immediate vicinity of the belt (sector *A*, 0 to 10 m from the shelterbelt) is surprisingly low. This is in good agreement with the results of earlier studies (Wilusz 1958, Kamiński 1967, unpublished experiments made in the Plant Selection Station of the State Farm at Rogaczewo from 1952–1958).

In 1969, in the field situated to the west of the shelterbelt production of vascular plants in sector *A* was about 15% lower than the average for the whole field. The following year, the decrease in production in the extreme sector of the field situated to the east of the belt was even greater, over 27% of the average production for the whole of the study field. In that year, decrease in primary production of the field was marked and in the next sector (*B*) was

in Rogaczewo (distr. Kościan)
and calculated (italics) in g of dry mass per m$^2$

Tab. IV

| rye and aestival a depth of | | Field weeds | | | Self-sown aftercrop | Grain sown | Total primary production of field |
|---|---|---|---|---|---|---|---|
| 30 cm | 100 cm | vernal total | aestival upper parts | total | | | |
| 124.25 | 135.05 | 8.92 | 66.33 | 75.25 | 21.67 | –12 | 983.34 |
| | *175.20* | 8.67 | 45.33 | 54.00 | 18.00 | –12 | 1182.89 |
| 125.50 | 136.41 | 15.07 | 57.67 | 72.74 | 32.67 | – 12 | 1094.90 |
| | *175.20* | *11.90* | 62.00 | 73.90 | 28.00 | –12 | 1222.68 |
| 204.25 | 222.01 | *11.90* | 86.33 | 98.23 | 60.33 | –12 | 1176.52 |
| | 175.20 | 11.90 | 63.88 | 75.78 | 34.93 | –12 | 1159.27 |
| 81.25 | 88.32 | 5.10 | 20.70 | 25.80 | 9.33 | –12 | 732.28 |
| | *168.30* | 2.67 | 20.20 | 22.87 | 26.33 | –12 | 907.49 |
| 178.75 | 194.72 | 6.20 | 18.00 | 24.20 | 36.33 | –12 | 1027.60 |
| | *168.30* | 18.17 | 22.30 | 40.47 | 26.66 | –12 | 1066.34 |
| 145.25 | 157.88 | 20.49 | 18.50 | 38.99 | 29.00 | –12 | 1061.17 |
| | 168.30 | 12.01 | 19.77 | 31.78 | 28.73 | –12 | 1006.89 |

almost 10% of average production. This reduction in combined production of the field in sectors directly adjacent to the shelterbelt was due chiefly to lower production of the upper parts of rye plants.

The effect of the shelterbelt was even greater on rye grain production (Tab. IV). In sector *A* there was 36% less grain in 1969 than the average crop from the field, and in 1970 there was 22% less, but in that year decrease in the grain crop was also found in sector *B*.

Distance from the shelterbelt had practically no effect on other components of the primary production of the field (weeds, selfsown aftercrop on the stubblefield).

It must of course be emphasised that in our studies no comparison was made

Primary production of rye fields in Rogaczewo. Results in g and % of dry mass per $m^2$

Tab. V

| | Field section | Rye | | | | | | | | Weeds total | | Self-sown aftercrop | | Grain sown | Total primary production of field | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | above-ground parts | | | | roots | | total | | | | | | | | |
| | | vegetative | | grain | | | | | | | | | | | | |
| | | g | % | g | % | g | % | g | % | g | % | g | % | g | g | % |
| West field in 1969 | A 1–10 | 599.7 | 60 | 163.7 | 16 | 124.3 | 13 | 887.6 | 89 | 86.0 | 9 | 21.7 | 2 | −12 | 983.3 | 100 |
| | B 10–50 | 675.7 | 57 | 272.0 | 23 | 167.2 | 14 | 1114.8 | 94 | 62.0 | 5 | 18.0 | 1 | −12 | 1182.9 | 100 |
| | C 50–100 | 611.1 | 55 | 254.0 | 23 | 127.9 | 12 | 993.0 | 90 | 81.3 | 7 | 32.7 | 3 | −12 | 1094.9 | 100 |
| | D 100–150 | 674.6 | 55 | 283.0 | 23 | 164.7 | 13 | 1122.2 | 91 | 84.5 | 7 | 28.0 | 2 | −12 | 1222.7 | 100 |
| | E 150–200 | 563.0 | 48 | 245.0 | 20 | 199.5 | 17 | 1007.4 | 85 | 120.8 | 10 | 60.3 | 5 | −12 | 1176.5 | 100 |
| | 1–200 | 627.8 | 54 | 258.1 | 22 | 162.2 | 14 | 1044.1 | 90 | 88.3 | 7 | 34.9 | 3 | −12 | 1159.3 | 100 |
| East field in 1970 | A 1–10 | 456.0 | 62 | 164.2 | 22 | 85.5 | 11 | 705.7 | 95 | 28.6 | 4 | 9.3 | 1 | −12 | 732.3 | 100 |
| | B 10–50 | 527.4 | 57 | 174.6 | 19 | 163.5 | 18 | 865.5 | 95 | 27.7 | 3 | 26.3 | 3 | −12 | 907.5 | 100 |
| | C 50–100 | 563.5 | 55 | 220.9 | 21 | 190.2 | 19 | 974.6 | 95 | 28.7 | 2 | 36.3 | 3 | −12 | 1027.6 | 100 |
| | D 100–150 | 618.5 | 58 | 224.4 | 21 | 163.8 | 15 | 1006.8 | 94 | 44.9 | 4 | 26.6 | 2 | −12 | 1066.3 | 100 |
| | E 150–200 | 621.3 | 58 | 226.0 | 21 | 154.4 | 14.5 | 1001.7 | 93 | 42.4 | 4 | 29.0 | 3 | −12 | 1061.2 | 100 |
| | 1–200 | 579.0 | 58 | 210.5 | 21 | 164.1 | 16 | 954.2 | 95 | 34.3 | 3 | 28.7 | 2 | −12 | 1006.9 | 100 |

between crops from our field, influenced – as a whole – by the shelterbelt, and crops not subject to such influences. Thus the results obtained apply only to differences in crops within the field adjoining the shelterbelt.

### 3.3. Ryefield production in different years

From comparison of data on the primary production of ryefield at Rogaczewo for four study years: Herbich's (1969) and our own (Tab. VI), it can be seen that combined production from the ryefields under examination is nearly 1 kg of dry mass per 1 $m^2$ of field. Irrespective of whether rye was sown in the given year in the field situated to the east (1966) or west (1969), this production is slightly higher in drier years (1966 and 1969), since the "Włoszanowskie" variety of rye sown on these fields yields higher crops in drier years. Such adaptation to fairly dry conditions is reflected in grain crops: 28.5 q/ha in 1969 and 22.9 in 1970; this means 25.8 and 21.0 q/ha in dry mass.

Primary production of the same rye fields in different years in g d.m./$m^2$

Tab. VI

| Year | Rye | | Aestival weeds | Grain sown | Production of field | Vernal weeds | Self-sown aftercrop | Total primary production of the field |
|---|---|---|---|---|---|---|---|---|
| | Above-ground parts | Roots** | | | | | | |
| 1965/66* | 871 | 144 | 20 | -14 | 1021 | 12*** | 31*** | 1064 |
| 1966/67* | 809 | 139 | 37 | -14 | 971 | 12*** | 30*** | 1013 |
| 1968/69 | 885 | 175 | 64 | -12 | 1112 | 12 | 35 | 1159 |
| 1969/70 | 790 | 168 | 20 | -12 | 966 | 12 | 29 | 1007 |
| Average | 839 | 157 | 35 | -13 | 1018 | 12 | 31 | 1060 |

*Data for years 1965/66 and 1966/67 after Herbich (1969).

**Together with the aestival weeds.

***Data after our own estimates.

### 3.4. Rye population structure and dynamics

The combined production from the ryefield examined varies only slightly from year to year (deviation from the average for four years does not exceed 10%), and combined production of the upper parts of rye plants varies even less. The greatest differences, up to as much as 70%, are found in the mass of weeds which, however, form only an inconsiderable part of the field's production.

The case is different if we analyse the development of the rye population, taking into consideration changes in density of shoots per 1 $m^2$ (and consequently their mortality) and the resulting changes in biomass. For this analysis, only the data from 1969 and 1970 were used.

Before starting the basic studies, an estimate was made in the spring of 1970 of the density of rye soon after snow had disappeared (April 14th). The rye plants were still small and in successive sectors the average values per 1 $m^2$ were as follows:

| *A* | *B* | *C* | *D* | *E* | average |
|---|---|---|---|---|---|
| 373.3 | 436.6 | 373.3 | 356.7 | 373.3 | 382.6 |

No traces of decay or drying up of shoots could then be observed, despite the fact that the snow cover remained for an exceptionally long time that winter. Reduction in density thus did not begin until later, after the full tillering rye.

After the long-lasting snow cover and high rainfall in the spring of 1970 (Tab. II) the rye population developed differently from that of the previous year, when the weather was nearly average. It was found (Tab. VII) that:

a) Average density of sterile shoots was greater in spring at the time of maximum growth of the rye plants;

b. Biomass of rye per 1 $m^2$ of the field was greater at that time;

c. Density of culms with ears during harvest time, was almost identical;

d. Elimination due to dying of sterile shoots was far more intensive, resulting in considerable reduction in density and decrease in shoot biomass, this being enhanced by the weather conditions at the beginning of summer;

e. Biomass of the upper parts of rye, estimated when fully ripe before harvesting, was far lower. After adding the biomass of sterile shoots, the combined production of upper parts of rye plants in 1970 did not differ greatly from that of 1969;

f. There were fever culms with well-grown ears and more with incompletely formed ears, but the number of all culms remained almost unchanged (Tab. VIII);

g. There was a lower grain yield.

The comparison shows that in addition to sterile shoots being eliminated by dying, there is also, during the process of development and ripening, differentiation of rye into culms which attain full development and form well-grown ears and into culms which dry up before attaining complete development. This process also took a more favourable course for the "Włoszanowskie" rye in the dry year of 1969, resulting in a more favourable ratio of well-grown to poorly developed ears.

Comparison of density and biomass of rye in two different years

Tab. VII

A. Density of shoots per m² of field

| field section | in spring | | in summer | | difference | |
|---|---|---|---|---|---|---|
| | 1969 | 1960 | 1969 | 1970 | 1969 | 1970 |
| *A* | 1137 | 930 | 317 | 337 | 820 | 593 |
| *B* | 667 | 1373 | 388 | 441 | 279 | 932 |
| *C* | 833 | 1274 | 410 | 444 | 423 | 830 |
| *D* | 770 | 1360 | 455 | 490 | 315 | 970 |
| *E* | 677 | 1258 | 457 | 435 | 220 | 823 |
| Average | 760 | 1294 | 424 | 442 | 336 | 852 |

B. Biomass of shoots per m² of field

| field section | in spring | | in summer | | biomass loss of vegetative shoots | |
|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| *A* | 239 | 142 | 591 | 530 | 172 | 91 |
| *B* | 140 | 216 | 889 | 555 | 59 | 147 |
| *C* | 175 | 196 | 776 | 657 | 89 | 128 |
| *D* | 162 | 216 | 891 | 705 | 66 | 138 |
| *E* | 142 | 204 | 762 | 713 | 46 | 133 |
| Average | 160 | 203 | 815 | 656 | 71 | 134 |

Tab. VIII

| Year | Average number of ears per 1 m² | | |
|---|---|---|---|
| | well-developed | poorly developed | Total |
| 1969 | 260 | 26 | 286 |
| 1970 | 183 | 82 | 265 |

## 4. DISCUSSION OF THE METHOD AND RESULTS

Our method of assessing primary production, permitted to include the organic matter which dies before the time of maximum development, formed both by the cultivated plants and spring weeds. This method, used along with the harvesting one, has proved very useful. It made possible to estimate the organic matter actually produced on the field with relatively greater accuracy.

Herbich (1969) did not lose sight of dying organic matter of rye plants taking samples during the growing season with considerable frequency and calculating combined rye production by totaling the maxima of various organs. Consequently, however, she was obliget to limit the number of samples taken each time, and therefore unable to grasp the spatial differentiation of the field. Moreover, throughout the whole groving season she stayed at the place where her field study was conducted, and therefore her research was of a typically stationary character.

In our case, visits to the field were limited to several one or several-day operations, e.g. one day in March or April, several days in May, one in June, several days in July and one day in September or October. Studies thus arranged can be carried out not only in a stationary manner, but – if need be – in the form of expeditions lasting several days, and are therefore suitable for comparative assessments in different habitats and different parts of the country.

Since the density is estimated without taking any thing from the field, it is possible to ensure the accuracy of assessment by making an optionally large number of estimates, in spring when farmers are still occupied in the fields (spreading mineral fertilizers), and in summer on the stubble. In this way far less damage is done to crops, particularly in comparison with the harvest method of collecting large numbers of samples commonly used to assess primary production. Traczyk introduced this method with the intention of preventing damage to the herb layer in nature reserves. Preventing damage to crops on cultivated fields is, of course, of no less importance.

By including in the estimate even the less noticeable components of the annual production of the field (spring weeds, self-sowu after-crop on the stubblefield), greater accuracy of assessment was obtained than that achieved by previous author in the same field, and by other authors elsewhere.

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## PRODUKCJA PIERWOTNA POLA ŻYTA

### Streszczenie

W ramach zespołowych badań nad przepływem energii i obiegiem materii przez ekosystem pola uprawnego zapoczątkowanych przez Zakład Agroekologii PAN w Turwi przeprowadzono ocenę produkcji pierwotnej pola żyta.

Miejscem badań były pola Stacji Hodowli Roślin w Rogaczewie pow. Kościan, woj. poznańskie, przylegające od wschodu i zachodu do szerokiego alejowego zadrzewienia śródpolnego. Gleba obu pól jest piaszczysta. Zasobność w potas, fosfor i azot znaczna (kl. I), odczyn powierzchniowych warstw gleby na polu wschodnim słabo kwaśny, na zachodnim – obojętny do słabo alkalicznego. Segetalny zespół roślinny – *Papaveretum argemones* (Tab. I). Przebieg pogody w dwu kolejnych latach badań bardzo różny, zwłaszcza w okresie wegetacyjnym (Tab. II).

Płodozmian stały, dwupolowy polegał na kolejnym następstwie żyta i ziemniaków; agrotechnika była normalna, nawożenie mineralne intensywne, siew żyta wypadał w rok po oborniku; odmiana żyta – Włoszanowskie.

Celem badań było uchwycenie możliwie wszystkich elementów składowych produkcji pierwotnej pola w ich zróżnicowaniu przestrzennym przy niejednolitych, choćby z racji sąsiedztwa zadrzewienia, warunkach życiowych.

Najważniejsze założenia metodyczne to przeprowadzenie oceny szybko i łatwo, bez większego niszczenia zasiewu, aby można było taką ocenę powtarzać wielokrotnie w różnym czasie i miejscu.

Określono następujące elementy produkcji pola: żyto – części nadziemne i podziemne, chwasty – części nadziemne i podziemne, samosiewny poplon żyta i chwastów na ściernisku niszczony przez orkę jesienną.

Części nadziemne żyta oceniono metodą żniwną w momencie najsilniejszego rozwoju roślin przed żniwami. Dla uchwycenia pędów płonnych żyta, obumierających licznie przed jego dojrzeniem, zastosowano metodę Traczyka (1967) przystosowawszy ją do specyficznych warunków na polu żyta; metoda polega na ocenie zagęszczenia gatunków na badanej powierzchni oraz biomasy przeciętnego osobnika (pędu) i wyliczaniu produkcji pierwotnej przez pomnożenie tych dwu wartości.

Zagęszczenie i biomasę pędów żyta oznaczono dwukrotnie: na wiosnę w stanie rozkrzewienia ogólnego żyta, tj. maksymalnej liczebności pędów oraz w pełni dojrzałości żyta, w okresie żniw. Ponieważ nie wszystkie pędy strzelają w źdźbło i tworzą kłosy, lecz duża ich część obumiera wcześniej, do biomasy żyta stwierdzonej w pełni jego dojrzałości, tj. w stanie rozkrzewienia produkcyjnego, dodawano biomasę pędów płonnych, a więc tych, które nie strzeliły w źdźbło i nie były obecne na polu w okresie żniw. Korzenie żyta oznaczono z prób pobranych z warstwy ornej (do głębokości 30 cm) i do uzyskanych wartości biomas dodawano 8% na korzenie wrastające w glebę głębiej. Suszono i warzono korzenie razem nie oddzielając chwastów od żyta. Ich biomasę obliczono przyjmując, że stosunek biomas korzeni żyta i chwastów jest taki sam jak biomas ich części nadziemnych.

Nadziemne części chwastów letnich, rozwijających się równocześnie z żytem pobierano w próbach z dojrzałym żytem, lecz suszono i ważono oddzielnie. Chwasty wiosenne, rozwijające się w miedzyrzędziach żyta pobierano z systemami korzeniowymi.

Poplon samosiewny żyta i chwastów na ściernisku pobierano bezpośrednio przed jesienną orką.

Wyniki:

I. Produkcja pierwotna pola żyta jako całości wynosi około 1 $kg/m^2$ (Tab. IV i V). Wynik ten zgodny jest z osiągniętym poprzednio przez Herbich (1969) na tym samym polu oraz przez niektórych badaczy w NRF.

W tej masie materii organicznej ponad 75% stanowią nadziemne części żyta, a żyto wraz z korzeniami – 90–95%. Korzenie stanowią 16% całej produkcji pierwotnej i 18% części nadziemnych. Ten ostatni stosunek mieści się pomiędzy wartościami uzyskanymi przez autorów z Europy (13,73; 16,5; 22; 27,75%), a jest zupełnie odmienny od stosunku tych wielkości w suchych obszarach Arizony (269%).

Chwasty stanowiły w 1969 r. 7,6% i w 1970 – 3,6% łącznej produkcji pola. Wraz z poplonem samosiewnym wynosiło to odpowiednio 10 i 6,5% całości.

II. Produkcja pola w różnych odległościach od zadrzewienia (Tab. IV i V). Potwierdza się znane zjawisko wyraźnej zniżki produkcji w wąskim (0–10 m) pasie przylegającym do zadrzewienia w stosunku do reszty pola. Zniżka ta wynosiła w 1969 r. 15%, a w 1970 – 27% w porównaniu ze średnią produkcją pola, z tym że w 1970 r. zniżkę produkcji stwierdzono i w sektorze następnym z kolei (10–50 m).

Zmniejszenie produkcji pierwotnej na sektorze przylegającym do zadrzewienia spowodowane było głównie przez zmniejszenie części nadziemnych żyta. Wyraziło się ono też w zniżce plonu ziarna w 1969 r. o 36%, w 1970 o 22% w porównaniu ze średnim plonem z pola. Inne elementy produkcji pierwotnej były rozłożone na polu bardziej równomiernie. Nie ulega jednak wątpliwości, że rozrzut prób dla oceny produkcji takiego pola uwzględniać musi odległość od zadrzewienia.

III. Produkcja pola żyta w różnych latach. W ciągu 4 lat produkcja pól żyta (Tab. VI) wynosiła blisko 1 kg/m$^2$. Wyższa była w latach suchszych, niezależnie od tego, czy żyto wysiano na zachodniej czy wschodniej stronie zadrzewienia i jaką metodą produkcja była oceniana. Również plon ziarna wyższy był w latach suchszych (Tab. IV).

IV. Struktura i dynamika populacji żyta (Tab. VII). Łączna produkcja pierwotna pola żyta, a także produkcja całkowita rośliny uprawnej oceniona zarówno zastosowaną przez nas metodą, jak i metodą częstych prób i sumowania maksimów organów żyta zmienia się z roku na rok nieznacznie. Analiza zmian zagęszczenia i biomasy żyta w trakcie rozwoju wskazuje na to, że proces rozwoju prowadzący ostatecznie do takiego samego wyniku nie przebiega jednakowo (Tab. VII). Duże różnice w przebiegu rozwoju żyta stwierdzono w dwu kolejnych latach (1969 i 1970) różniących się bardzo przebiegiem pogody. W 1970 r. charakteryzującym się późnym zejściem pokrywy śnieżnej, dużymi opadami na wiosnę (IV i V) i suszą w czerwcu, stwierdzono w porównaniu z 1969 r.:-

1) większe średnie zagęszczenie pędów płonnych na wiosnę w momencie maksymalnego rozkrzewienia żyta;

2) Większą w tym momencie biomasę żyta na 1 m$^2$ pola;

3) Prawie identyczne zagęszczenie źdźbeł z kłosami w okresie żniw, tzw. rozkrzewienie produkcyjne;

4) Znacznie silniejszą eliminację przez obumieranie pędów płonnych, a zatem większą zniżkę zagęszczenia i ubytek biomasy pędów, czemu sprzyjały wybitnie warunki atmosferyczne;

5) Znacznie niższą biomasę części nadziemnych żyta dojrzałego; różnica ta zmniejszyła się znacznie po dodaniu biomasy obumarłych pędów płonnych;

6) Mniejszą liczbę źdźbeł z dorodnymi kłosami, a większą z kłosami niewykształconymi, przy prawie takiej samej łącznej liczbie źdźbeł;

7) Mniejszą masę ziarna.

Nasz sposób przeprowadzenia oceny produkcji pierwotnej pola żyta polegający na uzupełnieniu metody żniwnej metodą Traczyka (mnożenie biomasy przeciętnego pędu przez zagęszczenie) dla oceny biomasy obumierających przed dojrzeniem żyta pędów płonnych oraz objęcie oceną chwastów wiosennych i pożniwnej produkcji pola dały dużą dokładność wyników.

Ponadto przyjęty przez nas tok postępowania oszczędza w dużym stopniu zasiewy i pozwala przeprowadzać badania polowe również w trybie kilkudniowych ekspedycji, co umożliwia zastosowanie tej metody do badań porównawczych nawet w odległych miejscowościach.

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