

RESEARCHES REGARDING THE INFLUENCE OF THE PLANT DENSITY ON YIELD AND WATER USE EFFICIENCY IN MAIZE CROP FROM CRISURILOR PLAIN

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Abstract

The purpose of the paper was to optimize the plants density in maize from Crisurilor Plain for improvement of the water use efficiency. The paper is based on the research carried out during 2005 – 2007 in Agricultural Research and Development Station Oradea using the hybrid Turda super. The optimum water regime is based by ten to ten determinations of the soil moisture and maintaining the soil water reserve on watering depth (0-75 cm) between easily available water content and field capacity. The biggest water use efficiency at Turda super maize hybrid was registered at 55000 plants/ha in unirrigated conditions and in irrigated variant the greatest value was obtained at 70000 plants/ha density.

Key words: plant density, yield, water use efficiency, maize

INTRODUCTION

Maize is a vegetal specie with a big potential due a large utilisation like food sources for people and animals and for industry. Optimizing of the water regime assures the integral use of the yield potential of the maize hybrids. In the same time, natural resources of the water are more and more used as consequence decrease continuously and the increase of the water use efficiency in maize, the main crops from Romania, is an important objective.

Water is an essential element for every stage of plant development starting from germination to harvesting. In the international and Romanian literature the quantification of the water use efficiency is realized by indicators which emphasize all the water quantity used or irrigation water use (Muntean L.S. and al, 2008). The indicators present the problems of water use from two point of view: emphasize the quantity of yield or yield gain obtained on 1 liter water and emphasize the water used on 1 kilogram of yield.

Researches from international literature (Ogola J.B.O et al, 2005, Peake A.S et al, 2008) emphasized the influence of the density, and irrigation on water use efficiency in maize.

In the Crisurilor Plain, the researches regarding maize water use efficiency were published by Grumeza N. et al 1987, Domuta C., 2005;

Borza Ioana 2005, 2006, emphasized the climate and the technology elements influence on water use efficiency.

MATERIALS AND METHODS

The experience was placed by subdividing plots in in Agricultural Research and Development Station Oradea. The surface of the plot experience: 30 m². Number of repetition: 4. The experience had two factors: the water supply regime (irrigated and unirrigated) and plants density (25000 plants/ha, 40000 plants/ha, 55000 plants/ha, 70000 plants/ha and 85000 plants/ha).

The plants' water consumption was provided by the decade control of the soil moisture and by the application of irrigation when the water reserve decreased bellow easily available water content on the irrigation depth of the maize crop (0-75 cm). The optimum water consumption results at the end of the vegetation period, after the water balance in the soil is accomplished. (Domuta C., 2005). The water use efficiency (WUE) was calculated as a ratio between yield and water consumption, and the irrigation water use efficiency (IWUE) was calculated as the ratio between the yield gain achieved through irrigation and the irrigation rate. (Domuta C., 2005).

RESULTS AND DISCUSSIONS

1. The influence of the plants density on maize yield

In unirrigated conditions, in the year 2005 the biggest maize yield was obtained in the variant with 55000 plants/ha density (71,2 q/ha), followed by 40.000 plants/ha density with 63,1 q/ha yield; the lowest yield of maize 50,29 q/ha was obtained in the biggest plant density (85000 plants/ha). In the irrigated conditions the biggest yield was obtained in the variant with 55000 plants/hectare, too (83,60 q/ha) and the smallest in the variant with the biggest plants density, 85000 plants/hectare, 61,24 q/ha (table 1).

Table 1

The influence of the plant density on maize yield of theTurda super hybrid (q/ha) in unirrigated and irrigated conditions, Oradea 2005

| Nr. crt. | Variant | Water regime | | Average on density |
|-------------------|------------------|--------------|-----------|----------------------|
| | | Unirrigated | Irrigated | |
| 1. | 25.000 plants/ha | 57,80 | 69,30 | 63,55 ^{Mt} |
| 2. | 40.000 plants/ha | 63,10 | 75,20 | 69,15 ^{***} |
| 3. | 55.000 plants/ha | 71,20 | 83,60 | 77,40 ^{***} |
| 4. | 70.000 plants/ha | 59,70 | 70,20 | 64,95 ^{***} |
| 5. | 85.000 plants/ha | 50,20 | 61,24 | 55,72 ^{***} |
| Average on regime | | 60,40 | 71,91 | - |

| | Density | Water regime | Water regime x density | Density x Water regime |
|--------------------|---------|--------------|------------------------|------------------------|
| DL _{5%} | 2,14 | 3,10 | 3,62 | 3,10 |
| DL _{1%} | 3,20 | 5,20 | 5,86 | 4,90 |
| DL _{0,1%} | 4,70 | 9,70 | 10,20 | 7,20 |

In the year 2006, in unirrigated as well in irrigated conditions, the biggest yield of the maize was obtained in 70000 plants/ha density, 93,7 q/ha, respectively 112,4 q/ha. Irrigation determined an yield gain of 15,5 q/ha, very significant statistically. (table 2)

Table 2

The influence of the plant density on maize yield of the Turda super hybrid (q/ha) in unirrigated and irrigated conditions, Oradea 2006

| Nr. crt. | Variant | Water regime | | Average on density |
|-------------------|------------------|--------------|-----------|---------------------|
| | | Unirrigated | Irrigated | |
| 1. | 25.000 plants/ha | 73,00 | 80,10 | 76,55 ^{Mt} |
| 2. | 40.000 plants/ha | 81,00 | 97,80 | 89,40 |
| 3. | 55.000 plants/ha | 86,10 | 103,20 | 94,65 |
| 4. | 70.000 plants/ha | 93,70 | 112,40 | 103,05 |
| 5. | 85.000 plants/ha | 86,40 | 104,20 | 95,3 |
| Average on regime | | 84,04 | 99,54 | - |

| | Density | Water regime | Water regime x density | Density x Water regime |
|--------------------|---------|--------------|------------------------|------------------------|
| DL _{5%} | 2,32 | 3,46 | 3,64 | 2,86 |
| DL _{1%} | 3,20 | 5,30 | 4,98 | 4,2 |
| DL _{0,1%} | 5,18 | 7,10 | 8,28 | 7,09 |

In unirrigated conditions, in the year 2007, the biggest maize yield was obtained in 40000 plants/ha density, 61,0 q/ha, and in irrigated conditions in 70000 plants/ha density, 123,0 q/ha (table 3)

Table 3

The influence of the plant density on maize yield Turda super hybrid (q/ha) in unirrigated and irrigated conditions, Oradea 2007

| Nr. crt. | Variant | Water regime | | Average on density |
|-------------------|------------------|--------------|-----------|--------------------|
| | | Unirrigated | Irrigated | |
| 1. | 25.000 plants/ha | 53,20 | 90,20 | 71,7 |
| 2. | 40.000 plants/ha | 61,00 | 110,90 | 85,95 |
| 3. | 55.000 plants/ha | 57,60 | 121,00 | 89,30 |
| 4. | 70.000 plants/ha | 50,20 | 123,00 | 86,00 |
| 5. | 85.000 plants/ha | 41,30 | 109,70 | 75,50 |
| Average on regime | | 52,66 | 110,96 | - |

| | Density | Water regime | Water regime x density | Density x Water regime |
|--------------------|---------|--------------|------------------------|------------------------|
| DL _{5%} | 2,14 | 3,10 | 3,62 | 3,10 |
| DL _{1%} | 3,20 | 5,20 | 5,86 | 4,90 |
| DL _{0,1%} | 4,70 | 9,70 | 10,20 | 7,20 |

2. The influence of the plant density on water consumption in unirrigated and irrigated maize

In the year 2005, at the maize sowing, the water reserve on 0-150 cm depth was between 4810 and 4890 m³/ha, and in harvesting, the values were between 3020 și 3135 m³/ha. In the vegetation period of maize was registered 419,3 mm rainfall. For maintaining the water reserve on 0-75 cm between minimum level and field capacity were used an irrigation rate of 750 m³/ha. The irrigation determined the increase of the water consumption. In the variant with 85000 plants density were registered the biggest values of the water consumption in unirrigated (6073 m³/ha) also in irrigated (6733 m³/ha) conditions; the maize used more water from the soil reserve. (table 4)

Table 4

Total water consumption and covering sources in maize sowing in different plants density, Oradea 2005

| Variant | Water regime | $\Sigma (e + t)$ | | The covering sources | | | | | |
|------------------|--------------|--------------------|-----|----------------------|----|--------------------|----|--------------------|----|
| | | m ³ /ha | % | $R_i - R_f$ | | P_v | | Σm | |
| | | | | m ³ /ha | % | m ³ /ha | % | m ³ /ha | % |
| 25.000 plants/ha | Unirrigated | 5878 | 100 | 1685 | 29 | 4193 | 71 | - | - |
| | Irigated | 6703 | 114 | 1760 | 26 | 4193 | 63 | 750 | 11 |
| 40.000 plants/ha | Unirrigated | 5888 | 100 | 1695 | 29 | 4193 | 71 | - | - |
| | Irigated | 6733 | 114 | 1790 | 27 | 4193 | 62 | 750 | 11 |
| 55.000 plants/ha | Unirrigated | 5943 | 100 | 1750 | 29 | 4193 | 71 | - | - |
| | Irigated | 6703 | 113 | 1760 | 26 | 4193 | 63 | 750 | 11 |
| 70.000 plants/ha | Unirrigated | 5983 | 100 | 1790 | 30 | 4193 | 70 | - | - |
| | Irigated | 6723 | 112 | 1780 | 26 | 4193 | 62 | 750 | 12 |
| 85.000 plants/ha | Unirrigated | 6073 | 100 | 1880 | 31 | 4193 | 69 | - | - |
| | Irigated | 6733 | 111 | 1790 | 27 | 4193 | 62 | 750 | 11 |

$\Sigma (e + t)$ = total water consumption

$R_i - R_f$ = soil reserve (initial reserve – final reserve)

P_v = rainfall during the vegetation period

Σm = irrigation rate

The rainfall registered in the year 2006 in the vegetation period of maize were of 3550,0 m³/ha, and the optimum supply with water determined using an irrigated rate of 1160 m³/ha. Irrigation determined the increase of the water consumption values with 22-23%. The biggest values of the water consumption were registered in the variant with the biggest plants density of maize, 5490 m³/ha in unirrigated conditions and 6690 m³/ha in irrigated conditions. (table 5)

Table 5

Total water consumption and covering sources in maize sowing in different plants density,
Oradea 2006

| Variant | Water regime | $\Sigma (e + t)$ | | The covering sources | | | | | |
|------------------|--------------|--------------------|-----|----------------------|----|--------------------|----|--------------------|----|
| | | m ³ /ha | % | $R_i - R_f$ | | P_v | | Σm | |
| | | | | m ³ /ha | % | m ³ /ha | % | m ³ /ha | % |
| 25.000 plants/ha | Unirrigated | 5360 | 100 | 1810 | 34 | 3550 | 66 | - | - |
| | Irigated | 6560 | 123 | 1850 | 28 | 3550 | 54 | 1160 | 18 |
| 40.000 plants/ha | Unirrigated | 5460 | 100 | 1810 | 34 | 3550 | 66 | - | - |
| | Irigated | 6860 | 128 | 2150 | 31 | 3550 | 52 | 1160 | 17 |
| 55.000 plants/ha | Unirrigated | 5372 | 100 | 1822 | 34 | 3550 | 66 | - | - |
| | Irigated | 6615 | 123 | 1905 | 29 | 3550 | 54 | 1160 | 17 |
| 70.000 plants/ha | Unirrigated | 5415 | 100 | 1865 | 34 | 3550 | 66 | - | - |
| | Irigated | 6650 | 123 | 1940 | 29 | 3550 | 53 | 1160 | 18 |
| 85.000 plants/ha | Unirrigated | 5490 | 100 | 1940 | 35 | 3550 | 65 | - | - |
| | Irigated | 6690 | 122 | 1980 | 30 | 3550 | 53 | 1160 | 17 |

$\Sigma (e + t)$ = total water consumption

$R_i - R_f$ = soil reserve (initial reserve – final reserve)

P_v = rainfall during the vegetation period

Σm = irrigation rate

In the year 2007 in 85000 plants/ha density were registered the biggest values of the total water consumption 4490 m³/ha in unirrigated conditions and 6648 m³/ha in irrigated conditions. (table 6).

Table 6

Total water consumption and covering sources in maize sowing in different plants density,
Oradea 2007

| Variant | Water regime | $\Sigma (e + t)$ | | The covering sources | | | | | |
|------------------|--------------|--------------------|-----|----------------------|-----|--------------------|----|--------------------|----|
| | | m ³ /ha | % | $R_i - R_f$ | | P_v | | Σm | |
| | | | | m ³ /ha | % | m ³ /ha | % | m ³ /ha | % |
| 25.000 plants/ha | Unirrigated | 4038 | 100 | 420 | 10 | 3618 | 90 | - | - |
| | Irigated | 6238 | 155 | -330 | -5 | 3618 | 57 | 2950 | 48 |
| 40.000 plants/ha | Unirrigated | 4128 | 100 | 510 | 12 | 3618 | 88 | - | - |
| | Irigated | 6318 | 153 | -250 | -4 | 3618 | 57 | 2950 | 47 |
| 55.000 plants/ha | Unirrigated | 4188 | 100 | 570 | 14 | 3618 | 86 | - | - |
| | Irigated | 6393 | 153 | -175 | -3 | 3618 | 56 | 2950 | 47 |
| 70.000 plants/ha | Unirrigated | 4218 | 100 | 600 | 14 | 3618 | 86 | - | - |
| | Irigated | 6558 | 155 | -10 | 0,0 | 3618 | 55 | 2950 | 45 |
| 85.000 plants/ha | Unirrigated | 4490 | 100 | 872 | 19 | 3618 | 81 | - | - |
| | Irigated | 6648 | 148 | 80 | 1 | 3618 | 54 | 2950 | 45 |

$\Sigma (e + t)$ = total water consumption

$R_i - R_f$ = soil reserve (initial reserve – final reserve)

P_v = rainfall during the vegetation period

Σm = irrigation rate

3. The influence of the plants density on water use efficiency (WUE) in maize

In unirrigated conditions, in the year 2005, the biggest value of the water use efficiency was registered in 55000 plants/ha density, 1,2 kg/m³. In the same density was registered the biggest value of WUE 1,25 kg/m³ in irrigated conditions. (table 7)

Table 7

The influence of the plants density of the Turda super hybrid on water use efficiency (WUE) in unirrigated and irrigated conditions, Oradea 2005

| Density | Water regime | WUE | | Difference |
|------------------|--------------|-------------------|-----|------------|
| | | Kg/m ³ | % | % |
| 25.000 plants/ha | Unirrigated | 0,98 | 100 | - |
| | Irigated | 1,04 | 105 | 5 |
| 40.000 plants/ha | Unirrigated | 1,07 | 100 | - |
| | Irigated | 1,12 | 104 | 4 |
| 55.000 plants/ha | Unirrigated | 1,20 | 100 | - |
| | Irigated | 1,25 | 104 | 4 |
| 70.000 plants/ha | Unirrigated | 0,99 | 100 | - |
| | Irigated | 1,29 | 105 | 5 |
| 85.000 plants/ha | Unirrigated | 0,83 | 100 | - |
| | Irigated | 0,91 | 110 | 10 |

In the year 2006, the biggest value of the water use efficiency was obtained in 70000 plants/ha density in unirrigated conditions (1,73 kg/m³) and also in irrigated conditions (1,69 kg/m³). (table 8)

Table 8

The influence of the plants density of the Turda super hybrid on water use efficiency (WUE) in unirrigated and irrigated conditions, Oradea 2006

| Density | Water regime | WUE | | Difference |
|------------------|--------------|-------------------|-----|------------|
| | | Kg/m ³ | % | % |
| 25.000 plants/ha | Unirrigated | 1,36 | 100 | - |
| | Irigated | 1,22 | 90 | -10 |
| 40.000 plants/ha | Unirrigated | 1,51 | 100 | - |
| | Irigated | 1,43 | 94 | -6 |
| 55.000 plants/ha | Unirrigated | 1,60 | 100 | - |
| | Irigated | 1,56 | 98 | -2 |
| 70.000 plants/ha | Unirrigated | 1,73 | 100 | - |
| | Irigated | 1,69 | 98 | -2 |
| 85.000 plants/ha | Unirrigated | 1,57 | 100 | - |
| | Irigated | 1,56 | 99 | -1 |

In unirrigated conditions, in the year 2007, the biggest values of the water use efficiency was registered in 40000 plants/ha density, and in irrigated conditions in 55000 plans/ha density. (table 9)

Table 9

The influence of the plants density of the Turda super hybrid on water use efficiency (WUE) in unirrigated and irrigated conditions, Oradea 2007

| Density | Water regime | WUE | | Difference |
|------------------|--------------|-------------------|-----|------------|
| | | Kg/m ³ | % | % |
| 25.000 plants/ha | Unirrigated | 1,32 | 100 | - |
| | Irigated | 1,45 | 109 | 9 |
| 40.000 plants/ha | Unirrigated | 1,48 | 100 | - |
| | Irigated | 1,76 | 119 | 19 |
| 55.000 plants/ha | Unirrigated | 1,38 | 100 | - |
| | Irigated | 1,89 | 137 | 37 |
| 70.000 plants/ha | Unirrigated | 1,19 | 100 | - |
| | Irigated | 1,88 | 157 | 57 |
| 85.000 plants/ha | Unirrigated | 0,92 | 100 | - |
| | Irigated | 1,65 | 179 | 79 |

4. The influence of the plants density on irrigation water use efficiency (IWUE) of maize

In the year 2005, the biggest value of the irrigation water use efficiency was registered in 55000 plants/ha density, 1,65 kg gain/m³; in the other studied density, the values of IWUE was smaller (table 10)

Table 10

The influence of the plants density of the maize Turda super hybrid on irrigation water use efficiency (IWUE), Oradea 2005

| Density | IWUE | | Difference | |
|------------------|------------------------|-----|------------------------|----|
| | Kg gain/m ³ | % | Kg gain/m ³ | % |
| 25.000 plants/ha | 1,53 | 100 | - | - |
| 40.000 plants/ha | 1,61 | 105 | 0,08 | 5 |
| 55.000 plants/ha | 1,65 | 108 | 0,12 | 8 |
| 70.000 plants/ha | 1,40 | 92 | -0,13 | -8 |
| 85.000 plants/ha | 1,47 | 96 | -0,06 | -4 |

In 2006, the biggest yield gain, for 1 m³ of irrigation water used was registered in 70000 plants/ha density 1,61 kg yield gain/m³. (table 11)

Table 11

The influence of the plants density of the maize Turda super hybrid on irrigation water use efficiency (IWUE), Oradea 2006

| Density | IWUE | | Difference | |
|------------------|------------------------|-----|------------------------|-----|
| | Kg gain/m ³ | % | Kg gain/m ³ | % |
| 25.000 plants/ha | 0,61 | 100 | - | - |
| 40.000 plants/ha | 1,45 | 237 | 0,84 | 137 |
| 55.000 plants/ha | 1,47 | 242 | 0,86 | 142 |
| 70.000 plants/ha | 1,61 | 264 | 1,00 | 164 |
| 85.000 plants/ha | 1,53 | 252 | 0,92 | 152 |

In the year 2007, the biggest yield gain, obtained in 1 m³ of irrigation water used was registered in 70000 plants/ha density 2,47 kg yield gain/m³. (table 12)

Table 12

The influence of the plants density of the maize Turda super hybrid on irrigation water use efficiency (IWUE), Oradea 2007

| Density | IWUE | | Difference | |
|------------------|------------------------|-----|------------------------|----|
| | Kg gain/m ³ | % | Kg gain/m ³ | % |
| 25.000 plants/ha | 1,25 | 100 | - | - |
| 40.000 plants/ha | 1,69 | 135 | 0,44 | 35 |
| 55.000 plants/ha | 2,15 | 172 | 0,90 | 72 |
| 70.000 plants/ha | 2,47 | 197 | 1,22 | 97 |
| 85.000 plants/ha | 2,32 | 185 | 1,17 | 85 |

CONCLUSION

The plants density it is very important in optimizing of the maize vegetation factors regime. The researches carried out in Agricultural Research and Development Station Oradea used five graduation of the plants density and studied their influence on yield, water consumption, water use efficiency and irrigation water use efficiency.

In unirrigated and also in irrigated conditions, the maize plants density influence the values of the yield obtained. In unirrigated conditions, the biggest yield were obtained in 55000 plants density, except the dry year 2007, in wich the biggest yield were obtained in 40000 plants/ha density. In irrigating variants the greatest value of the yield was achieved at 70000 plants/ha density. In 2 years in unirrigated conditions the biggest water use efficiency (WUE) in maize was obtained at the 70000 plants/ha density.

In 2 from 3 years, of the research period, the biggest values of the irrigation water use efficiency (IWUE) in maize was obtained at the 70000 plants/ha density. In the technology of maize Turda super hybrid, in the Crisurilor Plain conditions, the recomandation is to use the 55000 plants/ha density in unirrigated conditions and 70000 plants/ha in irrigated conditions.

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