Götz, Sebastian and Bernhardt, Heinz

Procedure comparison between cross compound and normal sowing with silo maize

The following paper describes a field test carried out in 2008 to compare square planting and normal sowing with silo maize in special consideration of the effect on yield, weed regularisation, as well as work economy and profitability. Therefore cross compound should be examined as a new cultivation technology. The cross compound particularly stand out due to its sowing in a square compound of 33 by 33 cm. On this occasion, the single sowing rows connect precisely with each other. By creating cross compounds it is possible to hoe in two different directions: in the machine direction and also in a cross direction and consequently the weed free space is raised from about 66 % up to 90 %.

Keywords
Maize cultivation, spaced seed, hoeing, weed control

Abstract
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In consequence of the increase in fermentation-gas-capacity and the rising costs in dairy cattle farming you need an increase in efficiency in maize cultivation. Because of the expansion of cultivation in less suitable places negative aspects of the maize plant can be seen concerning soil erosion and weed suppression. Beside the yield oriented fertilization, erosion protection, soil-conserving land use and chemical plant protection have moved in the centre of agricultural and public interest. Especially in maize cultivation the weed regulation is absolutely needed. There is an extreme high loss of yield in maize cultivation particularly in no-till farming and insufficient herbicide use caused by weeds due to the weak competitive strength of the maize plant. In the United States yield losses from 40 % up to 80 % were documented [1]. In difference to grain where there is a threshold for each weed, maize should be weed free from the four up to the 8 leaf stage stage. Weeds before the 4 leaf stage and after the eight leaf stage have no economical effect. Although the mechanical weed regulation displaced by herbicides in the past changing conditions have revitalized the procedure. Growing Weed resistance against chemicals [2], loss of license by herbicides, and growing organic production, mechanical weed regulation will become more and more important. A main problem of the actual cultivation systems is the large part of uncultivated soil near the maize plants which cannot be reached by the mechanical hoe.

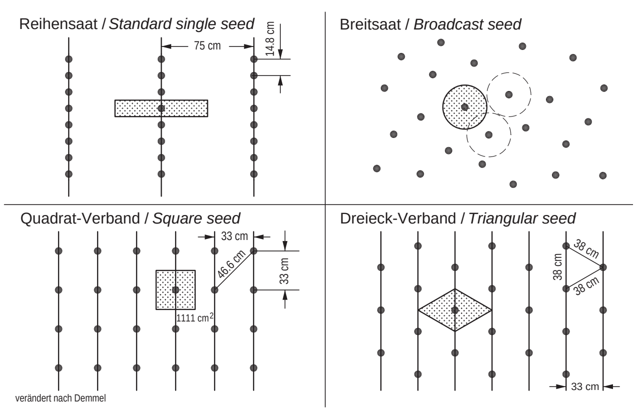
Especially maize growing, next to sugar beets and potatoes growing, has a negative effect on erosion in less suitable places, because of the high distance between the rows and the slow growth of the plants. On hilly plots, the combination of high precipitation in the summer and thin vegetation causes a high erosion potential and a loss of soil and nutrients. Precipitation energy reduction, puddle erosion, rising infiltration, off-flow of precipitation are in dependence on the vegetation [7]. With applying cross compounds, it is possible to hoe in two different directions: in the machine direction and also in a cross direction and as a consequence the weed free space is raised from about 66 % up to 90 % [3; 4]. An additional effect is a higher soil protection caused by reduced row distances. The technical solution for cross sowing is established by high precision GPS.

Definition of the equal space narrow row maize planting

In contrast to narrow row planting (37.5 cm row spacing), which is state of the art, the distance between rows in the equal space narrow row maize planting is reduced compared to normal sowing (75 cm distance between rows) as well as the deposition of adjacent maize grain is synchronized.

The seed distribution is carried out either in the form of squares or equilateral triangles, as shown in **figure 1**. A plant density of 9 plants per square meters is the result of a row spacing of 33 cm and a distance of 38 cm between plants resulting in the triangular structure. Under square planting both the spacing in the row and the distance between the rows are set to 33 cm.

Fig. 1



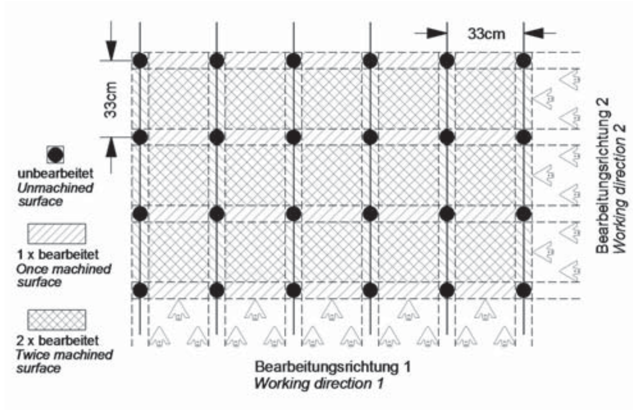
Theoretical seed distribution of different maize planting systems, modified after [5]

Material and methods

The point of the investigation is to become a quality and quantity statement about the GPS assisted sowing taken with simultaneous consideration of weed management and soil protection. Focus of the scientific experiment until 2010 is a precise pneumatic seeding machine for single seed, that is equipped with an electric drive for each seeding aggregate (sow disc). This machine in combination with a high accurate RTK-DGPS enables the process computer to establish rows in the trace-covering synchronisation of the seed deposit, as a condition of hoeing crosswise to the sowing direction.

The test surface (2008/2009) is at 290 m above sea level in. The annual precipitation on average amounts to 700 mm per year. The average annual temperature lies at 7.8 °C. The trial exists in two variations. The experiment set-up occurs in long plots in which the variations stand in alternate order side by side.

Fig. 2



Treatment frequency with two crossings

In the variation 1 the pneumatic corn planter is set on a row distance of 75 cm and a distance of the plants in the row of 13 cm. For weed regularisation a herbicide is used. In the second test variation a square planting of 33 cm is set up and mechanical weed regularisation is carried out. The row distance was reduced from 75 cm to 33 cm and the impulse of the single drill unit was synchronized. The real challenge of the cross sowing exists in the trace-covering synchronisation of the seed deposit, as a condition of a hoeing crosswise to the sowing direction **(figure 2)**.

In the attempt the weed regularisation is carried out with a rear-mounted toolbar with a broad duckfoot. First the weed population was inventoried at 20 places in the holding. After it has been hoed in the 4 and 8 leaf stage, the weed plants were counted out after each hoeing and the reduction cutback was calculated. The variations were managed in each case on approx. 2,500 m² with three recurrences planted and in company-customary intensity. The erosion protection effect of the test variations is derived from the degree of the vegetative soil cover, hence, digital pictures are made from the holding and dominance is calculated with a PC. The calculation of the harvest is carried out at square meter level, this way a thinning out of the maize plants through hoeing can be considered best. From each test plot 4 times 1 square metre is harvested by hand. The plants are first weighed and afterwards disassembled in leaf, maize-cob and stipe to weigh each individually.

Results

The evaluation of the data proved on average of all three plots of the variant 1 a plant distance in the row of 13.88 cm (± 3.5 cm) and a distance between the rows of 74.35 cm (± 2.5 cm). As a result in variant 2 remains for the record that the distance of the plants amounts on average to 32.30 cm (± 5.3 cm) and the distance between the rows 33.06 cm (± 2.0 cm).

Table 1

Average weed reduction (%) of well-chosen weeds by hoeing

Unkraut *Species*	**Reduktion** *Reduction* **(%)**
Windenknöterich *(Fallopia convolvulus)*	75
Weißer Gänsefuß *(Chenopodium album)*	72
Taubnessel *(Lamium purpureum)*	79
Hirtentäschel *(Capsella bursa-pastoris)*	65
Ackerhellerkraut *(Thlaspi arvense)*	69
Bluthirse *(Digitaria sanguinalis)*	67
Raps (Brassica napus)	63
Gänsedistel *(Sonchus oleraceus)*	67

On average of all plots and weed kinds in the cross compound the reduction lays with 73 %. The separate counting up in weed kinds proved no statistically secure tips to a different delicacy of the found types (**table 1**). By increasing weed size the effectiveness of hoeing decreased.

Furthermore the statistical evaluation shows that the significance of the weed reduction with $p \leq 0.05$ and partly clearly less, a reduction with all weeds.

With a clearance distance to the cultivated plant of 3 cm the state space of the culture amounts with the cross compound procedure 36 cm^2. With a stand density from 9 plants per square metre 324 cm^2 cannot be worked on what corresponds to 3.24 %. In the reverse the portion of the worked on surface lies with 96.76 %. **Table 2** shows the comparison of the worked on surfaces in the cross hoeing procedure and in inter-row hoeing. On average of the looked clearance distance the portion lies with worked on surface in the cross compound procedure by about 4.5% higher than in the inter-row hoeing. This also leads to an increased effectiveness in the weed suppression in the comparing to the inter-row hoeing.

The valuation of the cultural damage by hoeing in variant 2 proved by a sowing density of 9.5 plants per square meter to a cultural damage of 6.3 %. The subdivision of the damage shows a damage interest of 35 % with the hoeing in sowing direction and 65 % working crosswise to the sowing direction. The computer-assisted evaluation of the vegetation admissions proved on the admission day 10th of July, 2008 a covering of 40.46 % in the normal sowing (± 9.02 %). Taking the weed into account the maize in the cross compound reaches a covering of 61.83 % (± 6.81 %). The difference of the covering between normal sowing and cross compound is highly significant according to an ONEWAY ANOVA analysis with $p \leq 0{,}001$. The weights of the single plant parts sheet, maize-cob and stipee as well as the total weight of the maize plants in the cross compound were to the comparative parts of the normal sowing clearly higher ($p \leq 0{,}005$). The effect of the cultural procedure from the dry substance salary was not significant.

Table 2

Comparison of worked cropland in the inter-row hoeing (IRH) and in the cross-compound hoeing (CCH)

Sicherheitsabstand (cm) ***Clearance distance (cm)***		**1**	**2**	**3**	**4**	**5**
Bearbeitete Fläche (%) *Worked cropland (%)*	RHV *IRH*	97.33	94.67	92.00	89.33	86.67
	KHV *CCH*	99.68	98.72	97.12	94.88	92.00

Economic impact of equal space narrow row maize planting

The introduction of the cultural procedure to the practise depends beside the plant-architectural aspects also on the attacking costs, as well as the required working hours. The calculation of the costs shows that the narrow sowing of maize is for the example surfaces of one to twenty hectare plot sizes on average about 17.50 €/ha more expensive than the conventional sowing. Considered beside the costs per crossing (12–26 €/ha) also the costs for the herbicide of about 81 €/ha, so the total expenses lie between 92.67 €/ha and 106.69 €/ha. By application of a hoe the costs per crossing lie clearly higher than with the pesticide sprayer, nevertheless, the costs for herbicides are cancelled. If one settles the higher costs of the crossing with the saving of the herbicide, it appears that the mechanical variation from a plot size of 5 ha precipitates more favorably than the chemical alternative.

Furthermore the calculations show that the required working hours for the hoeing application lie on all examined plot dimensions with one to three hours clearly about the lead time of the chemical sprayer. Also in comparison to the normal inter-row hoeing the cross hoeing lies about around the factor two higher in the working time requirement, conditioned by two working directions. The working time requirement could be lowered by a temporal pawning of both crossings in different directions in possibly on that of the inter-row hoeing. At the same time the effectiveness of the weed regularization increases, because the multiple-worked on area (**figure 2**) is worked on not in the distance less hours, but in the distance several days, so that afterwards germinating weeds are grasped with the second crossing. The settlement of the increment with the add-on costs of the cross compound shows for the examined plot dimensions of 1–5 ha a necessary increment by cross compound in the scale from 2–6 % to receive a positive gross margin. Already from about 4 ha the costs of the cross compound lie lower than with the chemical protection of plants, indeed, the increased demand is always to be considered in working hours.

Conclusions

In tests it was proved that a level sowing provides not only benefit, but also environmental advantages as quicker shadowing of the ground, better nitrogen exploitation and with it lower N_{min} values are to be preferred after the harvest clearly to the other row distances. The raised standard deviation in variant 2 and the piled up appearance of plant losses of the crossing between two sowing tracks point to a too imprecise seed deposit.

This inaccuracy is caused by the mechanical power and slip of the driving wheels; hence, the seeds deposit must occur in future with electrical power. The exactness of the plant position is depending on the exactness of the delivery, rolling effect of the seeds and from the straight growth of the plant. After evaluations of Schulz Lammers these factors cause an inaccuracy of 2 cm [9]. Therefore the precision technology available today allows to place maize seeds so precisely without having to accept high plant losses with hoeing. The test has shown that corn sowing with the highest precision must be realized under high technical expenditure to be able to use a relatively easy procedure for weed control. On the part of the sowing technology the necessary conditions with RTK DGPS-steered grain filing (track to track) and a suitable design of the planter for exact grain filing without inadvertent rolling exist already on the market or is partly still in development.

Weed regularisation plays a central role in the maize cultivation, because the competition-weak cultivated plant cannot exist against the natural weed flora. Both hoeing measures (4 and 8 leaf stages) together reached an average weed reduction from 73 % and the aimed weed suppression in the sensitive 2–10 leaf stages of the maize plant. Relating to the found spectrum of weeds the analysis shows no significant difference of the hoeing in single weed types. On the one hand the weather dependence is lower with the hoeing, because no plant damages are to be feared by sun, temperature, or missing wax film, on the other hand, the ground must be dry to avoid structural damages by the hoeing tools and the tractor. The time frame, due to uncontrollable external influences, is basically the same for the mechanical and the chemical ground treatment.

With rising vegetative ground cover by the cultivation of crops the erosion danger of the grounds is diminished. A protective effect already begins with more than 30 % of steadily distributed plants or crop straw [6]. With the square planting the maize plants are distributed more favourably on the surface, so that a bigger surface part is covered at an earliest possible stage. In the normal sowing however leafs of several maize plants overlap clearly frequent and the big space between the rows can only be closed very late. The normal sowing reaches 2 months after the sowing a cover ratio of only about 10 % more than recommended 30 % to where the erosion decrease lies, while the cross association can already show the double cover ratio of the recommendation. Also eolian erosion can be reduced by the small-scale structure in cross compound. The profit inquiry at square metre level has shown that the cross sowing allows to expect a higher yield than the normal sowing. The relative increment to the base normal sowing amounts with the total weight to about 24 %. To field tests increased returns of 7–21 % or 9 % were ascertained with mechanical weed control [8]. Nevertheless, the single results are only difficult to compare, because annual influence, kinds influence and effects of the weather plays a role.

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Authors

Prof. Dr. Heinz Bernhardt is Ordinarius and M.Sc. Sebastian Götz is member of the scientific staff of the Lehrstuhl für Agrarsystemtechnik of the Technische Universität München, Am Staudengarten 2, 85354 Freising-Weihenstephan, E-Mail: sebastian.goetz@wzw.tum.de