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Development of a chamomile harvester

The cultivation of chamomile results in increased biodiversity in farms and in additional income sources. To make the harvest of chamomile flowers more efficient, a three-year research project was funded. The aim was the development and investigation of a research prototype characterized by a high picking quality, low losses, productivity of 1 hectare per hour, and low costs. In the final phase of the project a self-propelled harvester was tested, which provided the base for the future commercial manufacturing of the new harvester in small series.

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Abstract
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At the present time around 20,000 ha of chamomiles are grown worldwide for the pharmaceutical industry, including some 1,000 ha in the Federal Republic of Germany [1]. Cropping chamomiles increases biodiversity in the farming rotation as well as offering an additional income source for the farm. Currently, harvesting of this crop in Germany is by “Linz III” picking machines based mainly on earlier Fortschritt models (Kombinat Fortschritt Landmaschinen). Throughout their working life on the farms growing this crop, such machines have undergone alterations to their construction, including insertion of modernised working components. This resulted in progressive improvement. However, the last 15 years have seen neither research into developing new harvesting machinery nor production of modernised or new machines by German manufacturers. To encourage expansion of the chamomile crop and improve its efficiency the Ministry of Food, Agriculture and Consumer Protection (BMELV) funded, through the Agency for Renewable Resources in Germany (FNR) in Gülzow, a research project towards development of new harvesting machinery for chamomile flowers (FKZ: 22012309). The project was carried out from May 2010 to August 2013.

Its target was the development of a working prototype for a chamomile flower harvester, which – at a working speed of 1 ha/h – could give high picking quality, low losses and low costs.

The technical solution
Basics
In countries with low labour costs, chamomile harvesting still takes place by hand or with a low degree of mechanisation [2, 3, 4, 5]. Mechanisation is applied in countries with high wage levels (as in central Europe) using either tractor-powered or self-propelled machinery [1, 5, 6].

Because the principle applied in the flower picking operation is crucial in exploitation of performance potential and protection of harvested flower quality, particular attention is given in this paper to the development of the picking system. At present, the two dominant basic principles in mechanised harvesting of chamomile are the “picking comb” and the “picking rotor”. These are presented either as linearly driven picking combs with additional stalk shortener, or as rotating picking combs with inner and outer material discharge, or rotating peg drum [1, 7].

In Germany, driving self-propelled machinery up to a width of 3 m on the public road network (exception: autobahn) does not require special permission, meaning that the width of the harvester from hub to opposing hub should be within 3 m. Positioning the wheels at the outer edges of the machine, or picking unit, means every wheel track through the crop can be driven-on twice during the picking operation. Where the working width is larger than this, each track can be used only once. Only where the working width is > 6 m would something like the same proportion of the crop be travelled over per pass. Crop height, or picking horizon, in chamomile crops is very strongly variable from one small area to the next and this means that maintaining an optimal picking height is very hard to achieve with broad working widths [8, 9]. With this in mind, a higher driving speed was aimed for as an alternative method of achieving better area performance.

Trial results so far indicate that rotating picking combs in the form of a drum, as in the self-propelled Linz III harvester, offer good picking quality as well as acceptable area performance [10, 11, 12]. To further increase economic efficiency with harvesters for chamomile flowers, work must continue on improving technical solutions. With the Linz III, the picked flowers are delivered to the inside of the drum and from there transported by auger or belt conveyor to the flower bunker. During this operation, drum speed is limited to 20 to 25 rpm so that the flowers can be reliably deposited inside through force of gravity. In that a higher drum speed is required for improved harvesting performance, i. e. basically loss-free picking with increased driving speed, new technical solutions had to be found.

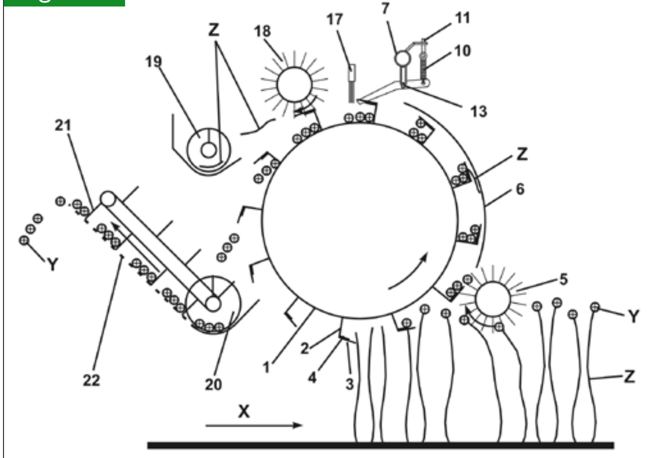
Technical design 2013

From 2010 to 2012 work was carried out on the development of a harvester whereby the picked material – as with the Linz III – was delivered to the inside of the drum [13, 14, 15]. Flowers were picked with picking combs positioned on the outside of the drum. At first, the aim was to deliver the picked flowers into the flower auger in the drum interior, even at higher drum speeds of > 30 rpm. To help in this transfer, a fan was used to create an air current to assist movement of the flowers out of the combs and into the flower auger. At the same time, double layer combs to give an action similar to a "mini mower cutter bar" were introduced in the first version, so that longer stalks remaining on flowers after picking could be shortened.

The transporting effect of the fan air current proved too weak and the double layer picking combs too easily damaged. This led to the introduction of a scissors-effect cutter bar for shortening stalks with shear elements of spring steel, a solution that proved robust and had more influence on keeping the picking comb clean. The airstream produced by the fan was additionally used to assist movement of the picked material from the inside of both drum halves over an injector gate and via pneumatic transport pipeline into the flower bunker.

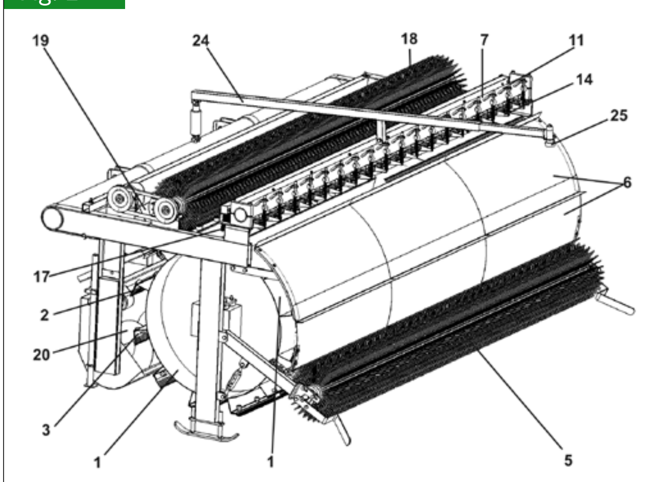
The 2012 harvest field trials showed that, even at medium drum speeds of around 40 rpm, discharge of flowers to the drum interior was unreliable with many flowers being thrown off backwards. This led to a cover being added which fully enclosed

Fig. 1



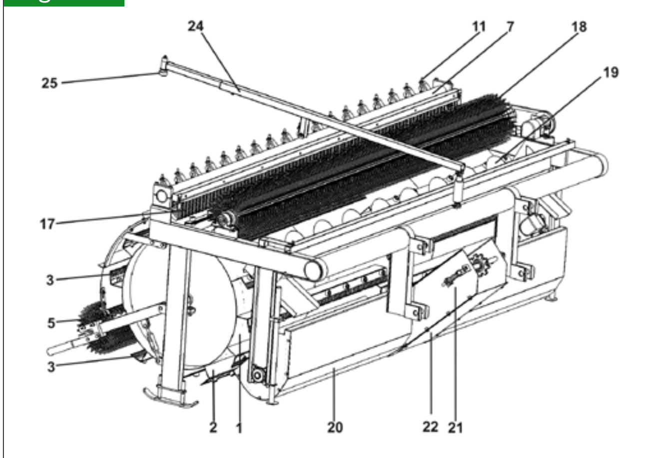
Principle of the picking unit from the KBEM'13 (X Driving direction)

Fig. 2



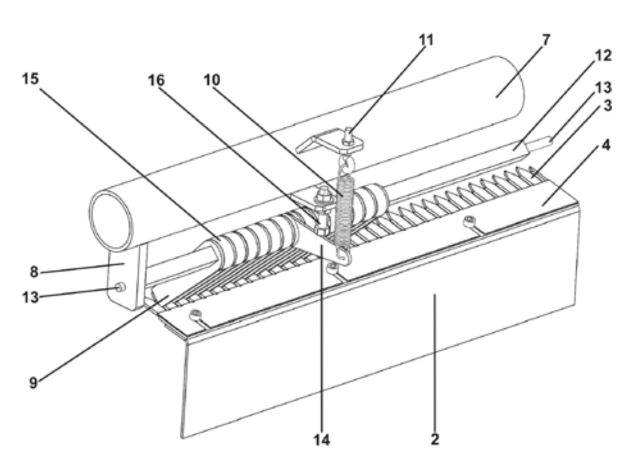
Picking unit of the KBEM'13 in perspective view (from right front)

Fig. 3



Picking unit of the KBEM'13 in perspective view (from left back)

Fig. 4



Shearing device for stalk cutting

the drum, the flowers being delivered into an auger behind the drum. This version offered three important advantages:

- Simple, continuous and robust structural design of the picking drum
- Avoidance of strips of insufficiently picked crop between the drum halves
- Replacement of pneumatic conveyance of harvested material into the bunker by belt conveyor or elevator

The 2013 harvester was based on the above developments, being equipped with a completely enclosed picking drum that discharged the harvested material outwards (**Figure 1** to **4**). The drum cover (1) was of sheet steel onto which angle brackets (2) for attaching the picking combs were welded. The comb attachment was exactly the same width as the picking comb (3) and, together with the picking comb, formed the picking channel. For improved practicality, each picking comb covered only half the drum breadth. Each drum half was equipped with 12 picking combs, therefore the entire drum had 24 picking combs. In order to achieve as smooth a running motion as possible the attachment brackets and, with them, the picking combs too, were arranged in a 15° offset pattern. The picking combs had a separation of 14.5 mm, of which the teeth accounted for 11 mm and the gaps 3.5 mm. Each comb had 100 teeth and a breadth of 1,446.5 mm.

In order to improve movement of the flowers onto the picking combs, a rotating feeder reel (5) was attached in front of the drum unit. The reel was not actively driven in the first version. As it was known from the previous trials that the picked flowers tended to spring out of the drum, a hood (6) was introduced.

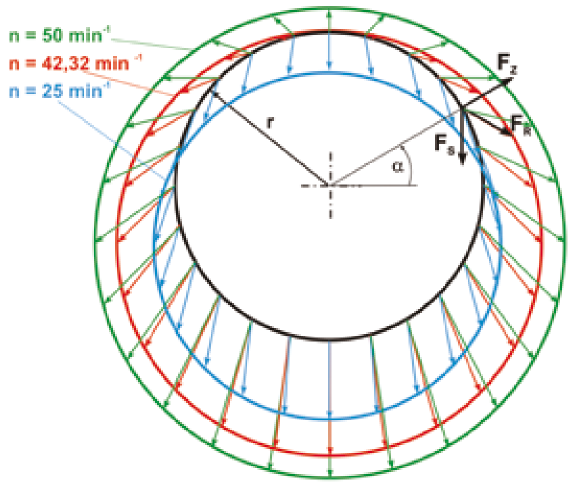
For shortening longer stalks left on the flowers, a new shearing device was introduced (**Figure 4**) with adjustable shearing power. Hereby, shear fingers (9), shear plate (4) and tension springs (10) are involved, with pre-tensioning possible via eyebolts (11).

So that the spring tension can be transferred to the shear fingers via form-lock, a square-cross-section hollow shaft with internal boring (12) is used as attachment element with the drive shaft, pivotally mounted on a through-running axle (13) thus preventing the rocker arm (14) rotating against the shear fingers. The shear fingers are so positioned on the square-cross-section hollow shaft that they slot exactly into picker comb spaces. With a stop screw (16), the cutting depth of the shear fingers can be steplessly adjusted.

Slots were bored into the shear plate to allow readjustment and therefore longer working life. This prevents the shear fingers moving onto the comb base and the resultant loss of shearing effect that should be achieved with the thin shear plate. The shearing system in this version has the advantage that thickest stalks are driven through the block positioning of the shear combs with the highest amount of power, while the areas of the shear plate without stalks have no, or very little, contact with the shear fingers.

To support the deposition of the flowers in the picking channel, as well as the cleaning of longer plant material from the combs, a rigid comb brush (17) and an actively driven cleaning brush (18) are positioned behind the shearing unit.

Fig. 5



$$|F_R| = \sqrt{(mg)^2 + (m\omega^2 r)^2 + 2gm^2\omega^2 r \sin\alpha}$$

Acting forces on a flower depending on rotation speed n = 25, 42.32 and 50 min^{-1}

The cleaning brush, as well as keeping the respective combs free of remaining vegetation, has also the task of propelling the longer portions of the picked material (Z) separated from the cutter bar into the vegetation conveying auger (19). From there, the material is deposited on the field surface onto the left hand wheel track so that it does not represent an obstacle to further picking.

In the development of the picking unit, it was expected that the flowers (Y) would be transferred in a tangential orbit underneath the stem-conveying auger and into the flower auger. With that in mind, the forces involved, and how they acted on individual flowers as a result of the rotating movement of the picker drum with radius of r = 0.5 m under different rpm of 25, 42.32 and 50 (**Figure 5**), were analysed. It became clear that with a low speed of 25 rpm the resultant lower centrifugal force F_Z limited the outer throw effect so that a dependable delivery of the flowers could only be expected in the lower region of the picking drum with $\alpha > 180°$. With a rotation of 42.32 rpm the gravity F_s and the centrifugal force have the same sum, i.e. where $\alpha = 90°$ the resultant force is zero whereas where $\alpha = 270°$ this represents twice the gravitational force. With a further increase in drum speed to 50 rpm the centrifugal force increases substantially, whereby an earlier discharge of the flowers where $\alpha < 180°$ out of the picker drum resulted.

After leaving the picking drum the material is transported in the flower conveyor auger (20) to the centre of the machine to be transferred by paddle elevator (21) onto a cleated belt conveyor for filling the flower hopper. For separation of fine material (e.g. sand) from the harvested material, the paddle elevator has a sieve floor (22) through which the finer particles can fall onto the field surface.

Fig. 6

Chamomile harvester KBEM'13 while testing (Photo: ATB)

To make it easier for the machine operator to control picking height, an ultrasonic sensor (25) was installed, positioned on a telescopic arm (24) sufficiently ahead of the picking unit.

Test results

Trials with the new harvester (**Figure 6**) in 2013 lasted from May 23 through to July 24. In evaluating the results, the general heterogeneity of the crop plant has to be recognised. Thus a trial on May 24, 2013 showed that the mechanically picked harvest amount differed by as much as 50 % within just a few metres. Even more differences in the respective crops were found between different fields with especially height, density and amount of foliage very different. Also, the number of pickings already carried out per crop area resulted in a change in harvesting conditions. Thus, comparisons of picking results from different localities are only possible to a very limited extent. For achievement of meaningful and reliable results a large number of samplings and a comprehensive trial design are therefore necessary [14, 15]. Limited capacity meant that this could only be partially achieved. This was especially so because, at the beginning, a large number of combined adjustment settings were tested and so it was difficult to deduce statistically reliable results regarding optimal operating speed, picking comb height or drum rpm. Also making this more difficult was the variability of the chamomile crop: an optimal machine setting for one site had to be readjusted on the next site because of the very different crop situations. Under these constraints the short time available during the 2013 harvest was used to comprehensively test the newly developed and previously untried principle of the chamomile harvester KBEM'13 and to deal with identified problems [16]. These problems were:

- Too high losses through non-optimal covering of the picking drum and design of the feeder reel
- Crop wrappage around rotating parts
- Too high transfer losses between paddle elevator and the belt conveyor for bunker filling
- Too high a proportion of flowers with short stalks remaining in the cross auger
- Too high a proportion of long plant material in the flower bunker
- Poor precision of the automatic picking height regulation in crops with weeds rising above the chamomile crop canopy
- Picking combs too liable to damage through stone contact

The continually amassed knowledge has led to steady further development and adjustment of the machine to meet requirements. The KBEM'13 proved itself finally in continuous operation. While it was not possible to solve all the identified problems, or to apply the required solutions, the findings of the work in 2013 still built a dependable basis for further development of the harvester [16] planned for the 2014 harvest season (**Table 1**).

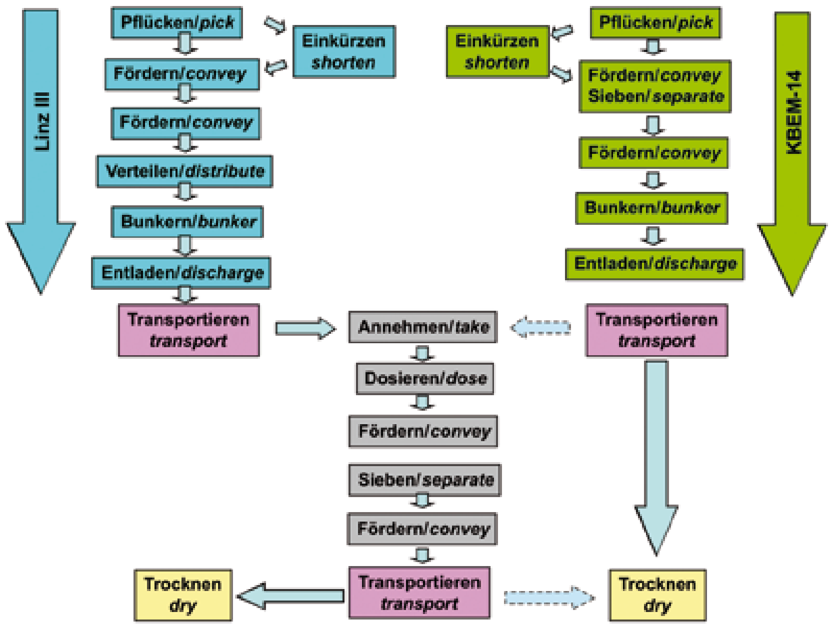
The most important results from the 2013 harvest season are the knowledge that the principle of the enclosed picking drum has proved itself and that, through the positioning of the

Table 1

Summary assessment of the chamomile harvesters

Bewertungskriterium ***Evaluation criterion***	**Linz III**	**KBEM'13**	**KBEM'14**
Ausführung der Pflücktrommel *Type of picking drum*	Innenabgabe *Inside discharge*	Außenabgabe *Outside discharge*	Außenabgabe *Outside discharge*
Trommeldrehzahl *Drum speed*	nach oben begrenzt *limited*	keine Begrenzung nach oben *unlimited*	keine Begrenzung nach oben *unlimited*
Spritzverluste *Hopping losses*	hoch *high*	hoch *high*	niedrig *low*
Einkürzung der Reststängel *Cutting of stalks*	begrenzt *limited*	möglich *possible*	möglich *possible*
Ablage von Langgut *Put down of long material*	im Pflückbereich *in the picking area*	vorrangig in der Fahrspur *mainly in the lanes*	vorrangig in der Fahrspur *mainly in the lanes*
Pflückgutqualität *Quality of picked flowers*	mit geringem Langanteil *with low long proportion*	mit hohem Langanteil *with high long proportion*	für Trocknung geeignet *useful for direct drying*

Fig. 7



Shortening the process chain by sorting on the harvester

sieve unit on the harvester, it is possible in principle to produce picked material that only has a very low proportion of flowers with a remaining stalk length > 3 cm. With this, the harvested material no longer needs to be put through a stationary separating unit before drying. Through including the sieve system on the harvester, the damage possibilities for picked material can be substantially reduced. Also greatly reduced can be the transport requirement as well as operational costs (**Figure 7**). As it can be assumed that picked material from the harvester is comparable in quality with that from a separation unit, direct delivery to a central or decentral drying unit is therefore possible.

First economic evaluations within this project show that through reduction of picking losses by something in the region of 10 % and the no longer necessary requirement of putting the harvested material through a stationary separation unit together offer increases in income in the region of several hundred euros per hectare for the crop.

Conclusions

With regard to the project target, it can be said that the aimed-for degree of picking efficiency has been achieved under conditions that could be termed favourable. But where the crop was dense with strong branching the target has not yet been reached. The quality of the picked material did not achieve the target level and definitely has to be increased through technical improvements. This applies especially to the proportion of flowers with still-attached stalks of under 3 cm. The area performance of 1 ha/h and more was reached when conditions were favourable. The trial results show that the number of unpicked flowers tends to increase in line with harvesting speed, i.e. when greater area performance is aimed for. With this as background, the farmer has to decide what is more important: high area performance or minimising loss.

Experience shows that it takes several years for a new picking principle to be optimised. This also applies to the KBEM'13 and to the machine that evolves from it in preparation for production of a small series of harvester models. Through the results achieved in the harvest season 2013, the knowledge that was gathered and the expectations of further optimising, it is anticipated that, after constructive revision a machine will be ready for the 2014 harvest: one capable of demonstrating clear advantages over the chamomile harvesters so far.

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