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Aspects of straw mulching in organic potatoes – II. Effects on *Potato Virus Y*, *Leptinotarsa decemlineata* (Say) and tuber yield

Aspekte der Strohmulchanwendung im ökologischen Kartoffelanbau – II. Wirkung auf *Potato Virus Y*, *Leptinotarsa decemlineata* und Knollenertrag

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Abstract

In a series of on-farm field experiments in organically grown potatoes the influence of straw mulch on the incidence of *Potato virus Y* (PVY), on the infestation with Colorado potato beetle (CPB, *Leptinotarsa decemlineata*), and on tuber yield was investigated over three years. Straw mulch significantly reduced PVY infection in three out of seventeen experiments; in seven further experiments there was a non-significant reduction of PVY. The effect of straw mulch on PVY incidence appeared to be dependent on the overall level of PVY infection, which differed between years, locations and varieties. For example, there was a consistent PVY reduction in 2002 and 2004, when the overall level of PVY infection was high. In contrast to this, no consistent trend could be observed in 2003, when there was a very low general PVY infection level. Straw mulch did not significantly affect the infestation with Colorado potato beetle in any of nine field experiments. However, in three experiments where three levels of straw were applied (nil, moderate amount and high amount), there was a consistent trend with the highest infestation in the unmulched treatment and the lowest CPB infestation at the highest amount of straw in eleven out of fifteen assessments. In five out of six field experiments there was no significant effect of straw mulch on tuber yield. Particularly, in two experiments conducted on lighter soils (loamy sand), straw mulch did not significantly affect yield or the size distribution of the tubers.

Key words: Colorado potato beetle, PVY, organic agriculture, seed potatoes, straw mulch

Zusammenfassung

In Praxisversuchen wurde über drei Jahre der Einfluss von Strohmulch auf das Auftreten von PVY (*Potato virus Y*), den Befall mit dem Kartoffelkäfer (*Leptinotarsa decemlineata*) und den Knollenertrag in ökologisch angebauten Kartoffeln untersucht. Strohmulch führte in drei von 17 Experimenten zu einer signifikanten Reduktion von PVY, und in weiteren sieben Versuchen gab es einen nicht-signifikanten Trend zur Verminderung von PVY. Der Effekt von Strohmulch auf PVY scheint vom allgemeinen Infektionsniveau abzuhängen, welches je nach Jahr, Standort und Sorte unterschiedlich war. So gab es in den Jahren 2002 und 2004 bei allgemein hohem Infektionsdruck eine konsistente PVY-Verminderung. Im Gegensatz dazu konnte im Jahr 2003, bei nur sehr geringem Infektionsdruck, kein konsistenter Trend beobachtet werden. Strohmulch hatte in keinem der neun Feldversuche einen signifikanten Effekt auf den Kartoffelkäferbefall; jedoch gab es in drei Feldversuchen, in denen drei verschiedene Mengen Stroh ausgebracht wurden (ohne Stroh, mäßige und hohe Aufwandmenge), bei 11 von 15 Bonituren einen konsistenten Trend mit dem höchsten Befall in der ungemulchten Behandlung und dem geringsten Befall bei der höchsten Strohaufwandmenge. In fünf von sechs Feldversuchen gab es keinen signifikanten Effekt von Strohmulch auf den Knollenertrag. Insbesondere führte in zwei Feldversuchen auf lehmigem Sand Strohmulch weder zu einer signifikanten Ertragsänderung noch zu einer veränderten Knollengrößenverteilung.

Stichwörter: Kartoffel, Kartoffelkäfer, Ökologischer Landbau, Pflanzkartoffeln, PVY, Strohmulch

Introduction

It was already reported by HEIMBACH et al. (2000) and SAUCKE and DÖRING (2004) that straw mulch may contribute to the reduction of *Potato Virus Y* (PVY) in potatoes. However, given the generally high variability of PVY incidence in potatoes between different locations and years (e.g., RIECKMANN and ZAHN, 1998), a reliable assessment of the potential benefits and limits of straw mulch for PVY control requires a larger set of observations, i.e. more field experiments. Moreover, results obtained under experimental small-plot conditions may not always apply to large-scale on-farm situations. In this paper we therefore report further results regarding the effect of straw mulch on PVY incidence in potatoes, obtained in on-farm experiments from four locations in Germany.

Various further aspects of straw mulch application in potatoes have been also described in former publications, including effects on aphid infestation of potatoes (DÖRING et al., 2006b), microclimate, late blight, and black scurf (DÖRING et al., 2006a), as well as effects on weeds, plant growth parameters, soil erosion, nitrate dynamics, and yield (DÖRING et al., 2005). In these latter field experiments conducted on silty and loamy soils, straw mulch was neutral to tuber yield. This was mainly attributed to the relatively low amounts of straw applied (2.5–5 t per ha) and the high water holding capacity of the soils. We therefore present yield measurements from two further experiments with straw

Tab. 1. PVY incidence in potatoes with and without straw mulch

Year	Site	Var.[a]	Exp.[b]	initial PVY [c]	prespr.[d]	tubers tested per treatment	PVY (%) in harvest[e] C	M	M+	Difference[f]	
2002	B	C	3	3.8	–	612	66.1	47.6		–	ns
	B	N	4	4.3	–	894	53.2	36.8		–	*
	C	L	6	4.8	–	329	79.6	68.5	49.0	–	*
	C	L	6	17.4[g]	–	389	91.1	77.6	69.6	–	**
	D	L	7	0	–	317	4.0	5.5		+	(ns)
	D	M	8	0	–	378	0.0	0.3		+	(ns)
2003	A	M	9	1.6	–	371	0.8	0.8		0	ns
	A	R	10	17.0	–	382	20.4	29.0		+	ns
	B	N	11	2.5	–	686	5.3	5.6		+	ns
	B	N	11	2.5	+	674	4.3	5.3		+	ns
	C	L	12	2.0	–	400	7.3	11.6	6.4	(+)	ns
	C	L	12	2.0	+	400	9.2	6.3	5.2	–	ns
	C	L	12	7.3[g]	–	400	11.3	9.9	15.4	(+)	ns
	D	L	13	0.0	–	228	3.4	6.3		+	ns
	D	L	13	0.0	+	317	14.5	13.7		–	ns
2004	A	M	14	0.0	–	503	1.2	1.1		–	ns
	A	S	15	13.0	–	529	59.5	55.6		–	ns
	B	C	16	4.3	–	692	4.4	3.0		–	ns
	B	N	17	7.4	–	512	10.4	9.1		–	ns
	B	N	18	7.4	+	542	10.2	9.4		–	ns
	C	L	19	8.9	–	379	44.4	34.1	36.2	–	ns
	C	L	19	8.9	+	372	42.1	35.1	29.0	–	ns
	C	L	19	12.1[g]	–	366	37.0	19.3	20.6	–	*
	D	L	20	1.9	–	800	1.4	4.1		+	ns

[a]: Variety: C: Christa, L: Linda, M: Marabel, N: Nicola, R: Rosella, S: Simone
[b]: Numbering of experiments; see Döring et al. 2006a; small scale experiments (Nr. 1 and 2) showed a significant reduction of PVY by mulch, published in SAUCKE and DÖRING (2004)
[c]: initial incidence of PVY in seed potatoes at planting
[d]: presprouting –: without, +: with presprouting
[e]: PVY incidence in harvested tubers; unmulched (C), mulched (M), and increased amount of mulch (M+)
[f]: Difference between unmulched (C) und mulched (M) treatment; –: M < C (reduction by mulch); +: M > C (increase by mulch); (+): average of mulched treatments higher than unmulched but without consistent trend; ns: not significant *: $p < 0.05$; **: $p < 0.01$
[g]: deliberately increased initial PVY incidence in seed potatoes

mulch applications on lighter soils (loamy sand) and with higher amounts of straw, as well as from four additional experiments on the heavier soils.

Finally, we also investigated side-effects of straw mulch on the Colorado potato beetle (*Leptinotarsa decemlineata*) (CPB). This species can cause considerable yield damage (HOFFMANN and SCHMUTTERER, 1999), and also in organic potato growing it is considered as an important pest species (MÖLLER et al., 2003).

Material and methods

Field experimental design

Seventeen field experiments were conducted over three years on four organically managed farms in Germany, at locations near Kassel (site A), near Göttingen (site B), near Braunschweig (site C), and near Rostock (site D). Details regarding locations, randomisation structure, soil type, dates of planting, mulching and harvest, plot sizes and pre-crops are described elsewhere (DÖRING et al., 2006a, Table 1). The numbers of experiments and names of locations are identical throughout both papers.

In the experimental sites A, B, and D, mulching with straw was compared to non-mulching, whereas in the three experiments at site C (6, 12 and 19), an additional third treatment with a higher amount of straw was included. In experiments 6, 11, 12, 13, 19, and 20, seed preparation (with and without presprouting) or certification level of seed tubers (different levels of initial virus infection) was included as an additional treatment factor.

Vector monitoring and Potato virus Y (PVY) diagnosis

In all years vector flight activity was monitored with two round yellow water traps after MOERICKE per location (diameter 22.5 cm). The traps were placed on bare soil. After harvest, eyes were cut from randomly selected tubers and plantlets were grown from these eyes in aphid free greenhouse chambers. Leaf sap obtained from the plantlets was then subjected to virus diagnosis by DAS-ELISA (CASPER and MEYER, 1981). We used non-strain-specific PVY antisera, either from BIOREBA (Switzerland) for analyses at site A, B, and D, or from BBA (Germany) (site C). The average number of tested tubers per treatment is given for each experiment in table 1.

Colorado potato beetle (CPB)

We assessed the infestation of potato plants with CPB in a total of nine field experiments at sites A, B, and C. For these assessments five different parameters were chosen: the number of egg clusters per 100 leaves (e_{CPB}); the number of larvae on 100 leaves (l_{CPB}); the number of adult beetles on 100 leaves (a_{CPB}); an index of leaf damage caused by the CPB estimated as the percentage of eaten leaf area (i_{CPB}); and the percentage of plants with more than 2 leaves damaged by the CPB (p_{CPB}). Table 2 summarizes which parameter was chosen on how many dates in each experiment. For parameters e_{CPB}, a_{CPB}, and l_{CPB}, 100 randomly chosen leaves were inspected per plot. In experiment 19, the index i_{CPB} was calculated as an average of leaf damage assessments from 110 to 220 individual plants per plot; this assessment was done on 13 July 2004.

Harvest and yield measurement

From site A, B, and C, we report yields from two experiments each (A: 14 and 15; B: 16 and 17; C: 12 and 19). The cumulative length of rows harvested per plot was 21 m in experiment 16; 25 m in experiment 14, 15 and 17; and 30 m in experiment 12

Tab. 2. Parameters for the assessment of the infestation with Colorado potato beetle: Number of assessments (dates) per experiment

Parameter[a]	Number of CPB assessments in experiment 6	9	11	12	14	15	16	17	19	all experim.
Egg cluster (e_{CPB})	0	2	3	0	3	3	4	1	1	17
Adult beetles (a_{CPB})	0	2	1	0	3	3	4	1	2	16
Leaves with larvae (l_{CPB})	3	2	1	2	1	1	2	0	3	15
Damage index (i_{CPB})	1	0	0	0	0	0	0	0	1	2
Damaged plants (p_{CPB})	0	3	2	2	0	0	0	0	0	7
all parameters	4	9	8	4	7	7	10	2	7	58

[a]: explanation see text (Material and methods section)

and 19. Harvested tubers were sorted with commercial potato sorters, partitioning the lots into three fractions (< 35 mm, 35–55 mm, and > 55 mm).

Statistical analysis

Statistical calculations were done with SAS v6.12 (SAS INSTITUTE Inc., 1989; SAS INSTITUTE Inc., 1990). All analyses of variance followed GLM procedures. All percentage values (e.g., tuber size fractions, virus incidence) were arcsin-square-root-transformed before further statistical analysis. Untransformed means are presented. For the statistical analysis of a variable over a set of experiments, the sign test after DIXON and MOOD (SACHS, 1999, p. 414) was used; here, a pair of observations consisted of the mean of the mulched treatment over all replications and the mean of the unmulched treatment.

Results

Virus vectors and Potato virus Y (PVY) incidence

Flight activity of virus vectors, measured with yellow water traps considerably differed between sites and years (Table 3). In all three years, the activity peak was highest at site A. While spring flight was high in 2002, and low in 2003 and 2004, summer flight activity was extremely high in 2003 and lower in the other two years. Also, the aphid species composition was different between sites and years, with *Brachycaudus helichrysi* and *Cavariella aegopodii* being dominant in 2002, *Brevicoryne brassicae* dominating in 2003, and no clear dominance pattern in 2004 (Table 3).

There was a strong effect of the year on the general level of PVY infection in all trials and locations, with the lowest level in 2003. It should be noted that *Myzus persicae*, which is often stated to be an important vector of PVY, was not abundant in the years 2002 and 2004, when the incidence of PVY in the harvested tubers was rather high, while the high flight activity of *M. persicae* in yellow water traps in 2003 did not push the incidence of PVY.

PVY incidence also depended on the potato variety, e.g. the highly PVY resistant variety 'Marabel' showed always very low infection levels (experiment 8, 9 and 14). In the 17 experiments presented, nine experiments showed a consistent reduction of PVY by mulch, which was significant in three experiments (Nr. 4, 6, and 19, Table 1).

Moreover, we found that the effect of straw mulch on PVY was dependent on the overall level of PVY infection. The PVY reducing effect of straw mulch appeared to be stronger when the general level of infection was higher. For example, while in 2003 there was no clear or consistent trend regarding the effect of straw mulch on PVY, the virus reducing trend in 2004, when infection risk was higher than in 2003, was significant according to the DIXON and MOOD sign test. Also, in 2002 experiments with a significant virus reducing mulch effect showed a higher overall PVY level than the experiments at site D where no significant mulch effect was observed. In experiments 6, 12, and 19, two levels of initial virus infection were compared within each experiment, which allows to directly test if the virus reduction efficiency of mulch is higher or more reliable when the infection risk is increased. In deed, for the moderate amount of straw, the relative virus reduction efficiency of mulch was higher in the treatment with the higher initial PVY infection in all three experiments, but this was not the case for the higher amount of straw in experiments 6 and 12.

Colorado potato beetle

Regarding the CPB infestation of potato plants, spatial effects were observed in almost all experiments. Typically, the adult beetles tended to invade the fields from the field margins. There was no significant effect of straw mulch on CPB infestation in any of the nine experiments at any time (Table 4). However, the number of cases where CPB infestation was (non-significantly) lower in the mulched treatment was higher than the number of cases with a reversed effect. Although this trend was observed for all para-

Tab. 3. Time of flight peak and aphid species composition in yellow water traps: classified dominance at the time of flight peak

Year	2002[b]			2003				2004			
Site	A	B	C	A[c]	B	C[d]	D	A	B	C	D
Number of aphids per day and trap at peak flight	116	28	58	1594	69	3	627	27	7	4	8
Time of flight peak (decade / month)	III/5	II/5	III/5	II/7	II/7	(I/5)	III/7	III/6	II/7	III/6	III/6
Species[a]											
Aphis fabae group									+	+	
Brachycaudus helichrysi	++	++	++								
Brevicoryne brassicae				++	+		+++				+
Capitophorus elaeagni										+	
Cavariella aegopodii	++	+	+								
Hyperomyzus lactucae								+			
Myzus persicae				+	++						

+: > 20%; ++: > 40% +++: > 60%
[a]: vector efficiencies for PVY see HARRINGTON and GIBSON (1989); HEIMBACH et al. (1998); HALBERT et al. (2003)
[b]: no yellow water traps were placed at site D in 2002
[c]: trap was placed near a faba bean field
[d]: aphid counts from nets placed in the crop and sprayed with insect glue indicate that also at site C there was a rather strong summer flight in July 2003; however, this was not observed in the yellow water traps for unknown reasons. Therefore, no species differentiation is given here

Tab. 4. Effect of straw mulch on infestation with the Colorado potato beetle, assessed with different parameters. Number of cases with lower, equal and higher infestation

Parameter[b]	M < C*	Number of cases[a] M < C ns	M = C	M > C ns	M > C*	Sum
Egg cluster (e)	0	8	5	4	0	17
Adult beetles (a)	0	10	3	3	0	16
Leaves with larvae (l)	0	9	1	5	0	15
Damage index (i)	0	2	0	0	0	2
Damaged plants (p)	0	5	1	2	0	8
All parameters	0	34	10	14	0	58

[a]: M: mulch; C: unmulched check; M < C: CPB infestation higher in unmulched than in mulched plots;
M = C: equal infestation; M > C: infestation higher in mulched plots
* statistically significant difference; ns: not significant
[b]: explanation see text (Material and methods section)

Tab. 5. Effect of straw mulch on tuber yield (dt/ha) and tuber size distribution

Exp.	Prespr.	Yield without straw	moderate level	high level	Mulch effect on total yield (%)[a]		small size fraction[b]		large size fraction[b]	
12	–	132	119	114	–9.8	ns	(+)	ns	–	ns
12	+	118	97	102	–17.8	ns	(–)	ns	(+)	ns
14	–	321	341	–	+6.2	ns	+	ns	+	ns
15	–	231	197	–	–14.8	ns	+	*	–	*
16	–	319	355	–	+11.1	ns	+	ns	+	ns
17	–	326	302	–	–7.2	*	+	ns	–	ns
18	+	353	341	–	–3.5	ns	–	ns	–	ns
19	+/–	193	214	205	+11.0	ns	+	ns	–	ns

[a]: (M-C)/C*100; with M = mulch and C = unmulched check; for experiment 12 and 19, M relates to the moderate amount of straw
[b]: +, –, (+), (–), see table 1, annotation f

meters, it was not significant when subjected to the DIXON and MOOD sign test in any case (SACHS, 1999, p. 415).

In the experiments 6, 12 and 19, where three levels of straw were applied (nil, moderate amount and high amount), there was a consistent trend with the highest infestation in the unmulched treatment and the lowest CPB infestation in the treatment with the highest amount of straw. This trend was observed with all four assessments in 2002, with three out of four assessments in 2003, and with four out of seven assessments in 2004.

Yield

Tuber yield strongly differed between sites, with generally lower yields at site C than at site A and B. Yield was not influenced by straw mulch in five out of six experiments, but was significantly reduced in experiment 17 by 7.2 %. In one out of six experiments (Nr. 15), the small size fraction was significantly increased while the large size fraction was significantly decreased by mulching.

Discussion

Compared to the results obtained in small scale field experiments (SAUCKE and DÖRING, 2004), the series of experiments presented here may at first give the impression that the reducing effect of straw mulch on PVY is not fully reproducible under on-farm conditions, as there were significant effects in only three out of 17 experiments. However, with this investigation we demonstrated that straw mulch is more efficient in situations of high virus infection risk, but has no consistent impact on PVY incidence when the overall level is low. In the small scale experiments the infection pressure was artificially increased by the use of infector rows for an increased initial infection at planting. Therefore, differences in the efficiency of straw mulch may be attributed more to the different infection levels than to the size or general type of the experiment.

It was already stated by SAUCKE and DÖRING (2004) that straw mulching will probably have a higher impact on PVY when vector flight is concentrated early in the year, i.e. when there is a strong spring flight of aphids. This was the case in 2002 and 2004, compared to 2003, when spring flight was very low. In some experiments, the application of straw mulch was quite late, especially at site D (see DÖRING et. al., 2006a, Table 1). Thus, relatively late mulching may explain lower mulching efficiencies, because then the vector spring flight may be missed. In summary, we regard straw mulch as an appropriate strategy for PVY control in potatoes in cases of high infection risk, especially for situations of a marked spring flight, given that mulch is applied sufficiently early, i.e. before the main aphid flight period.

Although the infestation of potato plants with the Colorado potato beetle was not significantly influenced by straw mulch in any of the nine experiments, in our view it is difficult to maintain that there was no trend at all. This is (a) because of the dose-effect-relationship in experiments 6, 12, and 19 and (b) the fact that we observed more cases with lower CPB infestation in the mulched treatment with all five parameters (Table 4). Moreover, experiments from other studies indicate a reducing effect of straw mulch on *Leptinotarsa decemlineata*. STONER (1993) found a lower number of first generation larvae and a lower extent of defoliation in straw mulched than in unmulched potato plots. Similarly, ZEHNDER and HOUGH-GOLDSTEIN (1990) showed that straw mulch applied to conventionally grown potatoes reduced the density of adults, egg clusters and larvae of CPB early in the season and reduced the number of insecticide treatments required to keep CPB populations below an economic threshold.

With sufficient caution it may therefore be concluded that there could be a weak trend of reduced CPB infestation by straw mulch which is hidden under the strong spatial effects associated with the typical pattern of colonisation from the field margin. On the other hand, it is also very clear from the presented series of field experiments that straw mulch does not influence the CPB infestation to an economically relevant extent, i.e. the small effects on the CPB alone will not justify the application of straw mulch.

Nevertheless, the combined beneficial effects of straw mulch on soil erosion, virus infection and nitrate dynamics may make the application of straw mulch an attractive cultural technique under conditions of high risk of soil erosion, post-harvest nitrate loss, or virus infection.

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