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Harvest loss in corn and implication for volunteerism

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Abstract

Nebraska is one of the top five corn-growing states in the United States, with the planting of corn on 3.5 to 4 million hectares annually. Harvest loss of corn results in volunteer corn interference in the crop grown in rotation. Estimating the extent of harvest loss and expected volunteer corn density is a key to planning an integrated volunteer corn management program. This study aimed to evaluate the harvest loss of corn and estimate the potential for volunteerism. Harvest loss samples were collected after corn harvest from a total of 47 fields in six counties, including 26 corn fields in 2020, and 21 fields in 2021, in south-central and southeastern Nebraska. An individual cornfield size was 16 to 64 ha. A total of 16 samples were collected from each field after corn harvest in 2020 and 2021. Harvest loss of corn was 1.5% and 0.7% of the average yield of 15,300 kg ha^{-1} in 2020 and 2021, respectively. Corn harvest loss was 191 and 80 kg ha^{-1} from dryland fields, and 206 and 114 kg ha^{-1} from irrigated fields in 2020 and 2021, respectively. An average kernel loss of 68 and 33 m^{-2} occurred in 2020 and 2021, respectively. The germination percentage of corn kernels collected from harvest loss was 51%, which implies that volunteer corn plants of 35 and 17 m^{-2} from 2020 and 2021, respectively, could be expected in successive years. A volunteer corn management plan is required, because if it is not controlled, this level of volunteer corn density can cause yield reduction depending on the crop grown in rotation.

Introduction

Corn is the most important crop in the United States. In 2022, corn was grown on 35.9 million ha with a production of about 348,700 million kg and an economic value of $91.7 billion in the United States (USDA-NASS 2022a). Corn is used for feed, human consumption, fuel, and industrial products such as oil, sweetener, and syrup (Ruan et al. 2019). Corn is an important export commodity of the United States, with about 62,700 million kg exports to 62 countries worldwide during 2021–2022 (USGC 2022). Corn is grown in most states, and Nebraska is one of the top five corn-producing states (Hunt et al. 2020). In Nebraska, corn was grown on 3.88 million ha in 2022, producing about 36,900 million kg (USDA-NASS 2022b). Harvesting corn from such a vast acreage is a tedious task, especially in unfavorable weather and when producers are short on labor and harvesting machinery, which can result in delayed harvesting, which increases the potential for harvest loss.

A portion of corn yield can be lost before and during harvesting. Multiple types of corn loss can occur at the time of harvest, such as losses at the header, which occur when cobs are missed or dropped before entering the header; from threshing, which occurs when the kernels are not properly shelled from the cob; and from separating, which occurs when kernels and debris are not properly separated at the back of the combine. In a survey conducted across 84 fields in Iowa, on average, 364 kg ha^{-1} corn harvest loss was observed, of which 132 kg ha^{-1} (36%) was preharvest loss, and 232 kg ha^{-1} (64%) was loss during combine harvesting (Vagts 2003). Similarly, a survey conducted in Missouri reported 19 to 290 kg ha^{-1} of corn harvest loss (Shauck and Smeda 2011).

Corn harvest loss may occur due to numerous reasons, such as poor crop conditions, adverse weather events, uneven field topography, higher combine travel speed, poor combine operating skills, improper combine setting, and others (Flint 2005; Pishgar-Komleh et al. 2013; Shauck and Smeda 2011). Combine settings that can affect harvest loss include concave clearance, cylinder or rotor speed, gathering snout height, and sieve and blower settings (Shay et al. 1993). Hanna (2008) reported that corn harvest losses of zero would be unlikely; however, losses can be reduced to ≤63 kg ha^{-1} in good standing corn if proper combine settings and procedures are practiced. Extreme weather such as hailstorms and high-speed wind at maturity can break down stalks and detach cobs, resulting in preharvest losses and volunteer corn infestation during the next growing season (Figure 1). Grain moisture content also influences the extent of harvest loss (Brandon 2009; Shauck and Smeda 2011). In a study conducted in Mississippi, Brandon (2009)

Figure 1. A windstorm in the fall before corn harvest led to downed corn in south-central Nebraska that resulted in volunteer corn next year in corn field near Hastings, Nebraska.

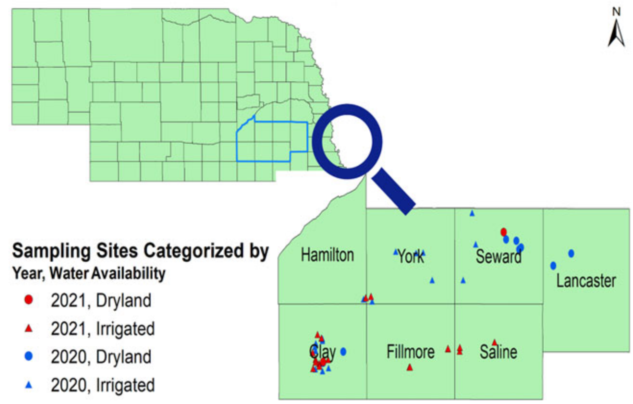

Figure 2. Nebraska state map with location of 26 corn fields sampled in 2020 and 21 fields sampled in 2021 to determine corn harvest loss. Source of map: U.S. Census Bureau.

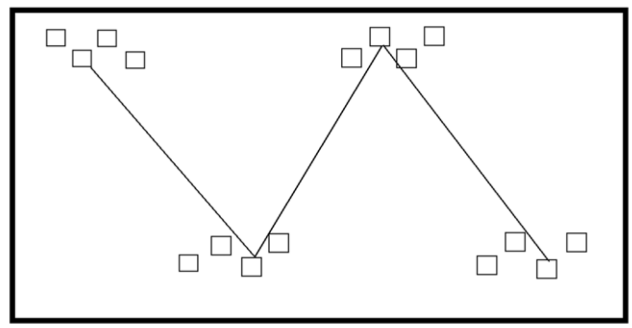

Figure 3. "W" pattern used for sampling to determine corn harvest loss in Nebraska.

reported that corn yield loss increased to 10% to 15% when harvested at 15% moisture content compared with 1% to 3% harvest loss at 26% moisture content. Similarly, in a survey conducted in Missouri, Shauck and Smeda (2011) found that corn harvest loss decreased by 52% with increasing moisture content from 13% to 16% to 21% to 24% at harvest.

Corn harvest loss acts as a double loss for producers: first, through direct loss in corn grain yield; and second, because the lost kernels germinate the following spring as volunteer corn and provide competition with the crop (Shauck and Smeda 2011; Thomison 2019). Corn volunteers compete for moisture, sunlight, space, and nutrients, thereby reducing crop yield and requiring herbicide application for their control (Chahal et al. 2014; Chahal and Jhala 2016). Volunteer corn is not only a problematic weed in corn-soybean [*Glycine max* (L.) Merr.] cropping systems (Beckie and Owen 2007; Chahal and Jhala 2016), but also in other corn-based crop rotations such as with sugarbeet (*Beta vulgaris* L.) (Kniss et al. 2012), edible dry beans (*Phaseolus vulgaris* L.) (Sbatella et al. 2016), cotton (*Gossypium hirsutum* L.) (Clewis et al. 2008), and continuous corn (Striegel et al. 2020) where seed corn or special-purpose corn is grown (Singh et al. 2024). Volunteer corn density of 10 plants m^{-2} can reduce corn yield by 19% (Steckel et al. 2009), and in a study conducted in Nebraska, volunteer corn at a density of 1 plant m^{-2} reduced soybean yield by 22% (Chahal and Jhala 2016). In a study conducted in North Carolina, Clewis et al. (2008) reported that volunteer corn density of 5.3 plants m^{-2} reduced cotton height by 38% to 43%.

Along with direct competition with the crop grown in rotation, volunteer corn has indirect effects by harboring insect pests and impacting insect-resistance strategies (Marquardt et al. 2012; Summers et al. 2004). Yield losses and insect-pest issues in the crop grown in rotation with corn due to volunteer corn infestation are not economical and hence demand a management plan (Jhala et al. 2021). Managing volunteer corn is challenging with some crops, such as corn (Striegel et al. 2020), because preplant tillage or interrow cultivation is largely unfeasible due to the prevalence of no-till practice (Chahal and Jhala 2016). This is because preemergence herbicides are ineffective and postemergence herbicide options are limited (Chahal et al. 2014), and because multiple herbicide–resistant corn hybrids are being adopted on a larger scale, further limiting herbicide options (Jhala et al. 2021). Numerous studies have been conducted to evaluate herbicide options for control of volunteer corn among different crops (Chahal et al. 2014; Chahal and Jhala 2015; Kniss et al. 2012; Sbatella et al. 2016; Striegel et al. 2020), but scientific literature does not exist on how much corn is lost during harvest from growers' fields in Nebraska and its effect on volunteerism. Thus, this study aimed to evaluate harvest losses of corn from commercial corn growers' fields in Nebraska and estimate their potential for volunteerism.

Materials and Methods

Sample Collection and Estimating Corn Harvest Loss

In 2020 and 2021, 47 corn fields were sampled from south-central and southeastern Nebraska across six counties: Clay, Fillmore, Hamilton, Lancaster, Seward, and York (Figure 2). A total of 26 fields were sampled in 2020, and 21 fields in 2021. The size of the sampled fields ranged from 16 to 64 ha. Fields were sampled within 2 to 3 wk after harvest with corn stover standing, yet not disked or bailed. A total of 16 subsamples were collected from each field by selecting four spots across the entire field following a "W" pattern (Crabb et al. 1994; Krupke et al. 2009), and from each spot, four samples were collected using a 0.25-m^2 quadrat (Figure 3). The 16 subsamples were combined to make a composite sample. Corn kernels and cobs with kernels attached were collected from the sampled areas, and the samples were stored in paper bags and dried. After 7 d, kernels were separated from cobs, and the total number of kernels was counted for each composite sample. After

Table 1. Corn plant stand, previous crop, nitrogen application, corn yield, and corn harvest loss in 26 fields sampled in 2020 in Nebraska.[a]

Field number	Water availability	Corn plant stand	Previous crop	Nitrogen application	Corn yield	Harvest loss
		Plants ha^{-1}		kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
1	Dryland	NA	Soybean	NA	NA	129.5
2	Dryland	NA	Soybean	NA	NA	134.7
3	Irrigated	83,980	Soybean	225	15,700	177.3
4	Irrigated	79,040	Corn	247	15,100	524.4
5	Irrigated	80,275	Soybean	225	16,300	248.9
6	Irrigated	80,275	Soybean	202	16,900	229.7
7	Irrigated	83,980	Soybean	196	15,900	77.4
8	Irrigated	79,040	Soybean	236	15,500	140.7
9	Dryland	64,220	Corn	258	14,400	171.1
10	Irrigated	80,275	Soybean	202	16,600	355.8
11	Dryland	60,515	Soybean	247	12,000	116.4
12	Irrigated	83,980	Corn	258	16,100	367.9
13	Irrigated	80,275	Soybean	225	16,300	138.9
14	Dryland	69,160	Soybean	208	11,000	91.8
15	Dryland	69,160	Soybean	202	11,500	135.4
16	Dryland	74,100	Soybean	225	12,700	152.7
17	Dryland	74,100	Soybean	225	12,400	594.5
18	Irrigated	80,275	Soybean	208	8,000	60.2
19	Irrigated	83,980	Soybean	212	16,200	142.1
20	Irrigated	83,980	Corn	269	16,800	91.3
21	Irrigated	83,980	Corn	247	16,900	180.6
22	Irrigated	83,980	Corn	269	16,800	162.6
23	Irrigated	83,980	Soybean	219	11,800	506.9
24	Irrigated	83,980	Soybean	219	12,700	124.9
25	Irrigated	83,980	Soybean	202	11,200	246.1
26	Irrigated	80,275	Soybean	208	16,800	144.0

[a]NA indicates not applicable; data from this field were not available.

all seeds were accounted, 100 kernels from each composite sample were weighed to obtain 100-seed weight, which was corrected to 15.5% moisture content.

Information such as corn variety/hybrid planted, row spacing, seeding rate, corn yield, previous crop, and whether the field was irrigated, or the corn was a dryland type was collected from each grower.

Seed Storage and Germination

After counting and weighing, kernels were put into a freezer at 3 C for 4 mo to undergo dormancy and mimic the winter temperature. After 4 mo, the seeds were removed from the freezer and remained at room temperature for 3 to 4 d before the germination test began. For the germination test, 16 seeds from each composite sample were put in a petri dish lined with two Whatman No. 1 filter papers that were fully saturated with water. The petri dish containing the seeds was then incubated in a growth chamber at 25 C and 12/12-h light/dark conditions. Seed germination counts were recorded every day for up to 2 wk, and germinated seeds were removed from the petri dish. Water was added to the petri dish to keep the filter papers saturated whenever required.

Data Analysis

Corn harvest loss and volunteer corn soil seed bank addition were estimated using Equation 1.

$$\text{Corn harvest loss (kg ha}^{-1}) = \text{kernel } loss \text{ m}^{-2} \times \text{hundred seed weight (kg 100 seed}^{-1}) \times 100 \quad [1]$$

Volunteer corn soil seed bank addition was calculated using Equation 2:

$$\text{Volunteer corn soil seed bank addition (germinable seeds m}^{-2}) = \text{kernel loss m}^{-2} \times \text{germination percentage} \quad [2]$$

Results and Discussion

Out of 26 fields sampled in 2020, 20 had grown soybean the previous year, and six had grown corn; eight were dryland (rainfed), and 18 fields were irrigated (Table 1). The mean corn population for dryland and irrigated fields was 68,542, and 82,196 plants ha^{-1}, respectively. On average, dryland and irrigated fields received 227 kg N ha^{-1} during the growing season. Average corn yield for the dryland and irrigated fields was 12,300 and 15,100 kg ha^{-1}, respectively. Overall, a harvest loss of 1.5% (210 kg ha^{-1}) of average (both dryland and irrigated) yield of 14,400 kg ha^{-1} was recorded, with 1.6% (191 kg ha^{-1}) harvest loss for dryland, and 1.4% (206 kg ha^{-1}) for irrigated fields. Harvest loss was <1.0% from 11 fields and >3.0% from three fields. There was an overall harvest loss of 210 kg ha^{-1}, slightly less than the 232 kg ha^{-1} corn harvest loss reported by Vagts (2003) in Iowa.

Of the 21 fields sampled in 2021, 16 had grown soybean the previous year, and five had grown corn; two were dryland, and 19 were irrigated (Table 2). The mean corn population for dryland and irrigated fields was 70,395, and 82,290 plants ha^{-1}, respectively. Dryland fields received 236 kg N ha^{-1}, whereas irrigated fields received 219 kg N ha^{-1}. The average yield for dryland and irrigated fields was 13,600 and 15,500 kg ha^{-1}, respectively. Harvest loss for dryland fields was 0.6% (80 kg ha^{-1}), whereas it was 0.7% (114 kg ha^{-1}) for irrigated fields. The average harvest loss was 0.7% (111 kg ha^{-1}) of the average yield of 15,300 kg ha^{-1}. Out of 21 fields, five fields had a harvest loss of more than 1%. In all fields, harvest loss ranged from 28 to 198 kg ha^{-1}, whereas Shauck and Smeda (2011) reported a corn harvest loss of 19 to

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Table 2. Corn plant stand, previous crop, nitrogen application, corn yield, and corn harvest loss in 21 corn fields sampled in 2021 in Nebraska.

Field number	Water availability	Corn plant stand	Previous crop	Nitrogen application	Yield	Harvest loss
		Plants ha^{-1}		kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
1	Irrigated	80,275	Soybean	225	17,300	192.6
2	Irrigated	81,510	Soybean	225	17,600	95.1
3	Irrigated	83,980	Corn	225	12,700	134.6
4	Irrigated	83,980	Soybean	225	14,300	118.1
5	Irrigated	83,980	Soybean	225	14,800	169.3
6	Irrigated	79,040	Soybean	213	11,400	92.2
7	Irrigated	83,980	Soybean	225	14,100	197.6
8	Irrigated	80,275	Soybean	213	16,200	122.8
9	Irrigated	79,040	Corn	225	16,600	164.0
10	Irrigated	80,275	Soybean	213	15,400	78.6
11	Irrigated	79,040	Soybean	213	16,000	168.0
12	Dryland	69,160	Corn	247	14,700	70.8
13	Irrigated	83,980	Soybean	202	16,300	62.7
14	Irrigated	83,980	Soybean	202	17,200	44.2
15	Irrigated	83,980	Soybean	202	17,200	28.3
16	Irrigated	83,980	Soybean	202	16,900	88.6
17	Irrigated	83,980	Soybean	208	10,400	27.5
18	Irrigated	83,980	Corn	247	18,200	115.2
19	Dryland	71,630	Soybean	225	12,500	89.0
20	Irrigated	80,275	Corn	247	16,000	126.8
21	Irrigated	83,980	Soybean	219	16,300	139.9

290 kg ha^{-1} in Missouri. Harvest loss in 2020 was almost double that of 2021, which can be attributed to five fields in 2020 having a harvest loss of more than 350 kg ha^{-1} (Table 1) due to the impact of green snap.

On average, 68 and 33 kernels m^{-2} of corn were lost in 2020 and 2021, respectively. The laboratory test revealed that the lost kernels had 51% germination, which implies that volunteer plants of 35 and 17 m^{-2} could be expected in the following growing season. This is because most corn kernels overwinter and emerge in the following growing season (Chahal and Jhala 2015). Because the corn kernels in this study were overwintered in the laboratory, the percentage of survival and germination might vary from actual field conditions. Moreover, under field conditions, some kernels could be lost to microbial decay and predation by animals and birds, which can decrease the survival of volunteer corn and subsequent infestations in the following growing season.

Volunteer corn is a competitive weed, and studies have shown that even low levels of infestation can result in yield loss. In a study conducted in Indiana, Marquardt et al. (2012) found that volunteer corn density of 16 plant m^{-2} can reduce soybean yield by 41%. Steckel et al. (2009) also found that a volunteer corn density of 10 plants m^{-2} reduced hybrid corn yield by 19% in Tennessee. Beckett and Stoller (1988) reported that volunteer corn density of 0.5 plant m^{-2} can reduce soybean yield by 25%. Furthermore, volunteer corn can harbor insect pests and interfere with insect resistance strategies; for example, volunteer corn can help to overwinter corn leafhopper [*Dalbulus maidis* (DeLong and Wolcot)] in areas with warm winters (Summers et al. 2004). Rotating soybean with corn ensures complete mortality of corn rootworm [*Diabrotica virgifera virgifera* (Leconte)] larvae, but the presence of volunteer corn plants in soybean fields allows corn rootworm to survive, which can infest the following year's corn crop (Krupke et al. 2009). Moreover, volunteer corn plants that germinate from seeds of *Bacillus thuringiensis* (Bt) corn hybrids have sublethal doses of Bt toxin (Krupke et al. 2009), which can accelerate Bt resistance in insects (Marquardt et al. 2013).

Practical Implications

A recent survey in Nebraska reported volunteer corn as the seventh most troublesome weed in corn-based cropping systems (McDonald et al. 2023). This is the first report to estimate the corn harvest loss and predict volunteer corn infestation from commercial corn fields in Nebraska. Estimating the extent of harvest loss and expected volunteer corn infestation is one of the first steps to reducing harvest loss and planning integrated volunteer corn management programs. The results of this study indicate corn harvest loss of 210 and 111 kg ha^{-1} in 2020 and 2021, respectively, which equals an average of 0.7% to 1.5% corn yield loss (although corn grain yield loss was more than 3% in some fields). This level of corn yield loss has a significant effect on the farming economy, and there is a need to reduce corn harvest loss to improve the economic well-being of corn growers and reduce efforts to manage volunteer corn in the crop grown in rotation. Moreover, harvest loss kernels can overwinter, and half of them can germinate the following season as volunteer corn, which competes with the crop grown in rotation. According to the results of this study, volunteer corn plants of 17–35 m^{-2} can be expected in the following year, and if left uncontrolled, this level of volunteer corn infestation can result in considerable interference, dockage, and yield loss of the crop grown in rotation. Therefore, the best management practices need to be adopted to reduce corn harvest loss and a plan should be implemented to control volunteer corn in crops grown in rotation.

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