Erosion of Potato Field as Affected by Drainage Canal Intervals of a Horizontal-ridge System

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Abstract: Previously, horizontal-ridge system has been shown effective in reducing soil erosion. But, it could cause water logging, which is detrimental to crop growth and yield. To solve this problem, drainage canal establishment might be reasonable. However, the evidence remains scarce. In this study, effect of drainage canal intervals on the volume of runoff, soil loss, and nutrient loss (N-total and P-total) were investigated. There were 4 drainage canal intervals applied to the 12 targeted plots (each sized 3 m x 3 m): R0, R1, R1.5, and R2 namely 0 m, 1 m, 1.5 m, and 2 m, respectively. In this case, R0 had no drainage canals and taken as the control. The measured runoff, soil loss, N-total loss, and P-total loss ranged 24.714 – 0.951 m^3 ha^{-1}, 0.002 – 0.507 ton ha^{-1}, 0.849 – 204.881 kg ha^{-1}, and 0.685 – 176.505 kg ha^{-1}, respectively. The results revealed that existence of drainage canal increased runoff, soil loss, and nutrient loss compared to the control. Amongst them, R1 gave the highest values of soil and nutrient losses followed by R1.5, R2, and R0 as the lowest, which was probably due to the difference in number of drainage canal existing: 12, 7, 5, and 0, respectively. In addition, it was noticeable for a sufficient data trend conformity of the measured nutrient loss to the data of soil loss, runoff, and rainfall within a positive correlation amongst them. The data further confirmed the effect of soil structure condition on the volume changes of both runoff and soil loss.

Keywords: drainage canal; horizontal-ridge; nutrient loss; runoff; soil loss

INTRODUCTION

Background

Potato is one of the agricultural products of horticulture that plays important roles for Indonesian food demands fulfillment (BPS, 2023). It has been reported to having valuable nutritional contents: carbohydrates, minerals, protein, and vitamins amongst others (Perdani et al., 2019; Saputrayadi & Marianah, 2018; Saputro et al., 2019). Adding to this, potato may be consumed in various kind of meals, dishes, and other kinds of processed food so that it can be potentially used for food diversification (Ismadi et al., 2021; Kusumiyati, 2017; E. Purnomo et al., 2014; Putra et al., 2019).

The number of potato demand in Indonesia tended to increase yearly due to the significant increase of population number and their incomes as well as rapid growth of potato processing industry (Asgar, 2013; Erlangga, 2023; Hidayah et al., 2017; D. Purnomo et al., 2018; Utami et al., 2015). The household consumption of potato has increased from 608.02 thousand tons in 2018 to 874.25 thousand tons in 2022 (BPS, 2023). The consumption increase in 2022 was 13.32% (102.79 thousand tons) of the 2021 consumption, and the consumption in 2022 has contributed 32.05% to the total domestic consumption of potato (BPS, 2023).

On the other hand, the number of domestic potato production tended to increase annually from 1.28 million tons in 2018 to 1.50 million tons in 2022, for which the last year increase was about 10.50% (142.93 thousand tons) over 2021 production (BPS, 2023). Along with this, export volume of potato in 2022 was 3,518 ton (i.e. 2,666 ton fresh product and 852 ton processed product), while the import volume was 191.05 thousand tons (i.e. 74.44 thousand tons fresh product and 116.61 thousand tons processed product). This might confirm that there is a great demand to potato for domestic consumption.

This great demand to potato has lead Indonesian farmers to cultivating potato more intensively. It has been reported that the harvested area of potato has increased from 68,683 hectares in 2018 to 76,728 hectares in 2022 (BPS, 2023). Potato (*Solanum tuberosum*) is known as a cool-weather crop that requires proper temperature for better crop growth and yield (Kusnandar et al., 2023; Utami et al., 2015; Zhou et al., 2017). Therefore, in Indonesia it is mostly cultivated in highland area (Asmara et al., 2022; Hidayah et al., 2017; D. Purnomo et al., 2018; Zulkarnain et al., 2017).

This cultivation practices, however, may highly risk the land to soil erosion, since the farmers commonly set the ridge for potato bed to be paralleled with slope direction (vertical-ridge system) (Henny et al., 2011; Muliastuty, 2015; Tamad et al., 2023). Instead of this conventional vertical-ridge system, a horizontal-ridge system of which the ridge for potato bed is set across slope direction (paralleled to contour) has been known to enable to decrease the soil erosion (Direktorat Perluasan dan Pengelolaan Lahan, 2014; Henny et al., 2011; Wijaya et al., 2010, 2019; Wijaya, Masrukhi, et al., 2020). In Henny et al (2011) the yield of potato was not affected by the applied horizontal-ridge system, but this was conversely in Wijaya et al (2010) of which the yield was reduced about 23%.

The result of the latter was thought related to the occurrence of water logging nearby the ridges that may alter soil drainage conditions. Such circumstance of high humidity, in turn, may become a favorable media for detrimental fungi to grow and carry rot disease to potato root and tuber (Aprisal, 2023). One of the possible solutions for this occurrence of water logging in a horizontal-ridge system is by providing drainage canal along the ridges. Unfortunately, data about the possible effects of drainage canal existence, particularly about drainage canal interval, on the soil erosion pattern of a horizontal-ridge system has yet been rarely documented.

Aims

Accordingly, this study on a horizontal-ridge system was aimed to investigate the effect of drainage canal intervals on volume of surface runoff, volume of soil loss, and volume of nutrient loss.

RESEARCH METHOD

Tools and Materials

The study was conducted at Serang Village, Sub-district Karangreja, Purbalingga Regency of Central Java Province in Indonesia (7° 02′ 75″ S and 109° 17′05.38″ E - 7° 02′ 65″ S and 109° 17′05.51″ E). The altitude of research site was 1198 m above sea level with a typical clay of volcanic Andosol soil (Table 1). Tools used in this study were standard soil ring sampler, soil oven, weight scales, measuring cup, stopwatch, roll meter, hoe, and sediment collector. While, the materials used were seeds of Granola potato (G_3), plastic sheet, plastic mulch, plastic bag, chicken manure, organic fertilizer (*petroganik*), and organic pesticide (Bio-P60).

Table 1. Initial soil properties of the research site observed

Parameter	Unit	Value
Total N	%	0.46
Available N	ppm	57.16
Total P	%	0.90
Available P	ppm	0.61
Sand	%	37.44
Silt	%	48.18
Clay	%	14.38
Soil texture		Loam

Source: Laboratory of Soil and Land Resources-UNSOED

Method

Land preparation

Weed and crop debris of the targeted field were initially removed, and the soil was plowed using hoe up to 20 cm depth. Subsequently, chicken manure and organic fertilizer (Petroganik, 2.5% C-org., 10-25 C/N ratio) were incorporated into the soil within dosage of 10 and 20 ton ha^{-1}, respectively. To this field, a set of 12 research plots was prepared, of which the land slope was set 5% (Figure 1). Each research plot sized 3 m x 3 m, for which the all edges were fenced using plastic sheet (20 cm embedded into the soil and 60 cm stand above the ground) as to isolating it from the surrounding. At the middle lower ends of the research plot, a sediment collector (plastic pail with top diameter 29.2 cm, bottom diameter 26.2 cm, and height from the bottom center 33.8 cm) was placed as shown in Figure 1. To these research plots, soil mounds for potato seed bed were prepared across the land slope (parallel to soil contour) as to adopting horizontal ridge-system. The soil mound had dimension of 40 cm width and 30 cm height. There were 5 rows of soil mounds available for each research plot (Figure 1). Between the top-end of each soil mound and the nearby plastic fence, there was an alley within 5 cm width.

Experimental design

The research was conducted by adopting a completely randomized design using a single factor within 3 replications. The factor (research treatment) employed was drainage canal interval within 4 levels of its application, namely R0 = without drainage canal, R1 = 1 m drainage canal interval, R1.5 = 1.5 m drainage canal interval, and R2 = 2 m drainage canal interval. A certain research plot was subjected to a certain type of drainage canal interval. Therefore, there were 12 research plots in total for the 4 types of drainage canal interval applied (Figure 1). Since the research plot sized 3 m x 3 m, there would be 0, 12, 7, and 5 drainage canals available for research plot with R0, R1, R1.5, and R2 treatments, respectively. The drainage canal was created by hoeing the soil mounds of the targeted research plot within 20 cm in width.

A week later, seeds of Granola potato (G_3) were planted upon the prepared soil mounds, of which each row consisted of 8 potato groves. Organic pesticide (Bio-P60) was then applied to the potato groves about once a week within a dosage of 10 ml l^{-1} water for plant care purpose.

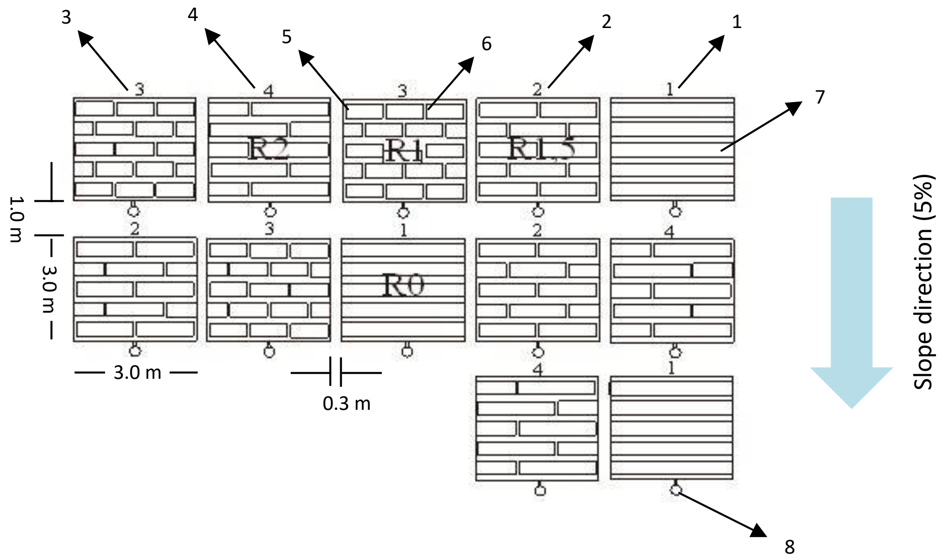

Figure 1. Research plots design and figure note: (1) plot without drainage canal (R0), (2) plot with 1.5 m drainage canal interval (R1.5), (3) plot with 1 m drainage canal interval (R1), (4) plot with 2 m drainage canal interval (R2), (5) alley, (6) drainage canal, (7) potato seed bed, and (8) sediment collector

Variables and measurements

Variables observed in this study were soil dry bulk density (g cm^{-3}), surface runoff (m^3 ha^{-1}), soil loss (ton ha^{-1}), and soil nutrient loss (kg ha^{-1}). Measurement of dry bulk density, surface runoff, and soil loss were conducted at 35, 43, 49, 56, 63, and 71 days after sowing (DAS). While, the measurement of soil nutrient loss was conducted at 35, 43, and 63 DAS. Along with these measurements, rainfall (mm) was also recorded using a rain gauge. For dry bulk density measurement, undisturbed soil samples were taken from any surfaces of soil mound of each research plot using standard soil ring sampler (100 cm^3) for 0 – 10 cm and 10 – 20 cm soil depth. Dry bulk density was then determined using gravimetric method after the soil sample has been oven-dried at 105°C for 24 hours. Surface run off was determined from the volume of collected run off in sediment collector per catchment area. Soil loss was determined from the collected soil sediment per catchment area after the soil sediment has been oven-dried at 105°C for 24 hours. Soil nutrient loss was assessed from the losses value of N-total (nitrogen) and P-total (phosphorus) namely N-total and P-total of the collected soil sediment per catchment area. In this case, values of N-total and P-total were determined using Kjeldahl and Colorimetric methods, respectively.

Data analysis

Data of surface runoff, soil loss, and soil nutrient loss was statistically analyzed using KaleidaGraph 4.1 software (Synergy Software 2012, USA) for analysis of variance (ANOVA). The post-hoc analysis was performed using Tukey's HSD test ($P < 0.05$).

RESULT AND DISCUSSION

Soil dry bulk density

Soil physical property of the soil mound for potato seed bed used in this study dynamically changed. This could be seen from the varied values of dry bulk density ranged 0.470 – 0.749 g cm^{-3} (Figure 2), even though there was no certain external forces applied to the soil mound, but only natural forces like rain drop as well as growing potato root and tuber those took place. Comparing between 0 – 10 and 10 – 20 cm in soil depth, the latter tended to having a greater dry bulk density, particularly in the plot with 2 m drainage canal interval treatment (R2). In case of the other drainage canal interval treatments (R0, R1, and R1.5), however, the result remained inconsistent. This discrepancy was probably due to the spatial difference and variability of the initial soil condition during soil mound preparation. If we take a look to the average value of dry bulk density obtained, research plot with drainage canal interval 1 m (R1) had the smallest value as of 0.552 g cm^{-3}, and research plot with drainage canal interval 2 m (R2) had the highest value as of 0.688 g cm^{-3} (Figure 3).

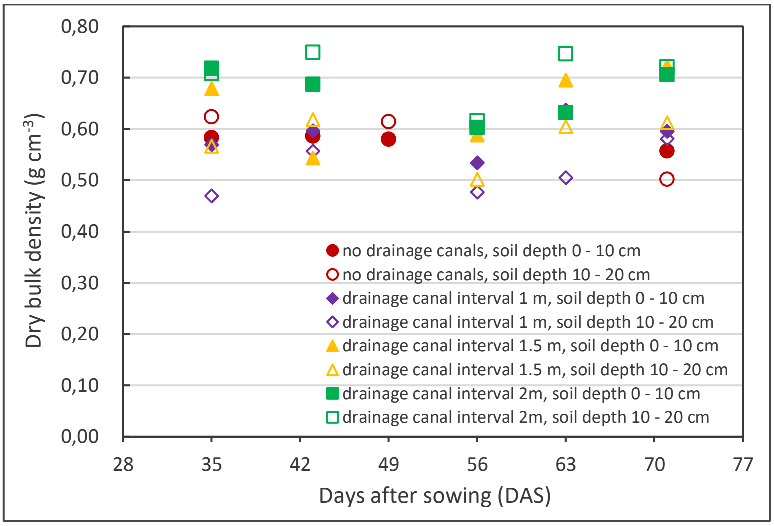

Figure 2. Variability in soil dry bulk density along the observation period

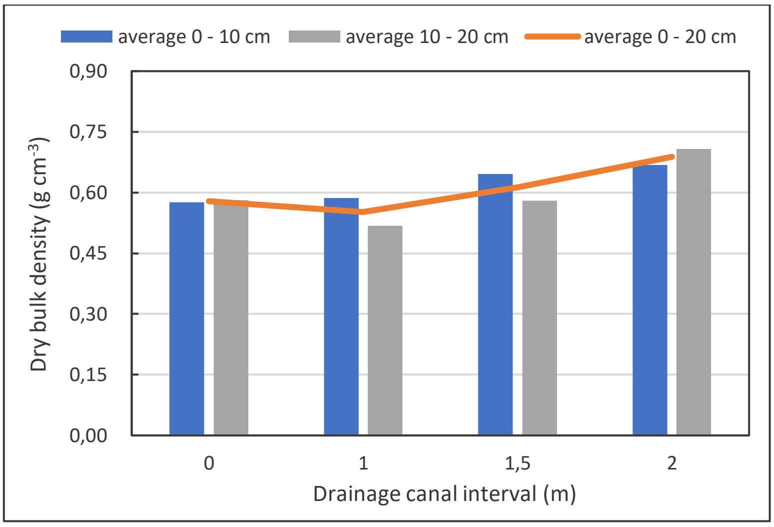

Figure 3. Average soil dry bulk density according to the applied drainage canal interval

Surface runoff

It could be seen from Figure 4 that the volume of surface runoff varied along the experimental period (24.714 to 0.951 m^3 ha^{-1}), and there was no certain patterns observed amongst the applied drainage canal interval treatments. For instance, research plot R0 resulted the highest runoff at 43 and 49 DAS, but gave the lowest runoff at 56, 63, and 71 DAS. Research plot R1.5 resulted the lowest runoff at 35 DAS, but gave the highest runoff at 56 and 63 DAS. Research plot R2, on the other hand, gave the lowest runoff at 49 DAS, but resulted the highest runoff at 71 DAS. Adding to this, the applied drainage canal intervals statistically gave no significant differences for the whole measurements conducted as shown in Table 2.

Notwithstanding, it could be yet inferred from Figure 4 that there was a positive correlation between the volume of rainfall and the volume of runoff encountered. The higher rainfall volume tended to result a higher runoff volume, and this was in a good agreement with Permana et al (2017) and Naharuddin (2020) who mentioned that rainfall is one of the determinant factors for surface runoff occurrence. Other than this, the volume of runoff tended to decrease along with the growth of potato crop. This result might imply a positive role of the existing potato crop in reducing surface runoff. It is well known that crop may act as a canopy that protects soil surface from the destructing energy of raindrop, by which stability of soil pore structure can be more maintained. Thus, soil infiltration can be more promoted, and the surface runoff becomes diminished (Ullyta et al., 2022; Wijaya, Masrukhi, et al., 2020). Similar with this, Nurmi et al (2012) has reported a greater infiltration, and thus a lower surface runoff, for weeds-covered land rather than an open-surface land. Further, Naharuddin (2020) has also mentioned that land covering by plant is another determinant factor for surface runoff occurrence.

If we take a look to the total and average values of runoff, research plot without drainage canal treatments (R0) gave the lowest values as of 80.365 and 13.394 m^3 ha^{-1}, respectively (Figure 5). These less values of runoff at research plot R0 were reasonably due to the absence of drainage canal upon the horizontal-ridge system applied so that the rainwater had less passage to flow upon the soil surface, and therefore had more time to infiltrate into the soil. In line with this, Henny et al (2011) has reported that a horizontal-ridge (parallel to contour or across the slope) may act as barrier and speed breaker to surface runoff, by which the rainwater had more time to infiltrate. Thus, surface runoff at research plot R0 in this present study seemed to take place only through the alley between the top-end of each soil mound and the nearby plastic fence of the research plot observed (Figure 1). This condition, in turn, may promote the occurrence of water logging near the ridge of the horizontal-ridge system employed (Henny et al., 2011; Wijaya et al., 2019, 2010; Wijaya, Masrukhi, et al., 2020).

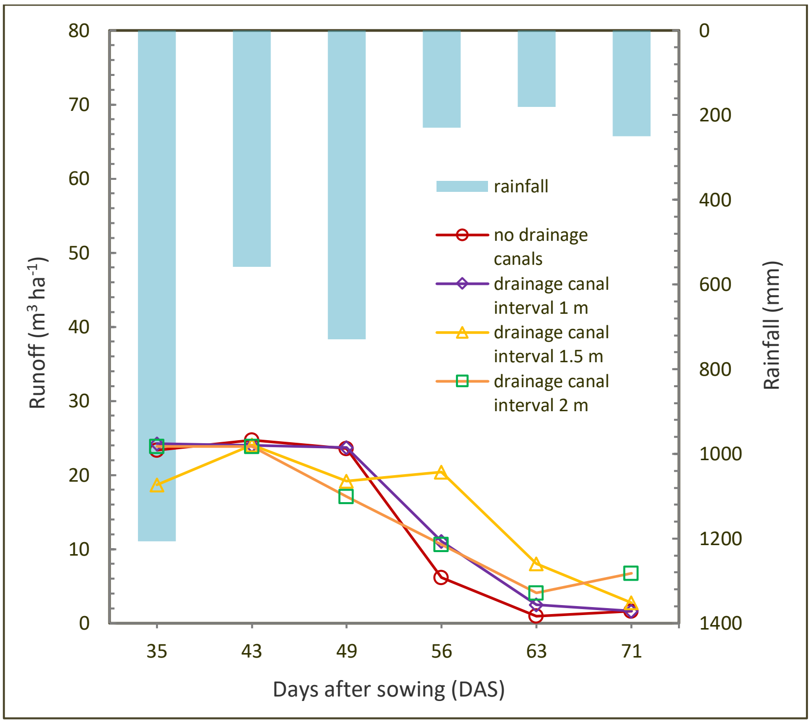

Figure 4. Runoff variability along the observation period

Table 2. Runoff values along the observation period

Drainage canal interval (m)	Runoff (m^3 ha^{-1})					
	35 DAS	43 DAS	49 DAS	56 DAS	63 DAS	71 DAS
0	23.333 ± 0.963a	24.714 ± 0.888a	23.605 ± 0.314a	6.133 ± 9.415a	0.951 ± 0.117a	1.629 ± 0.513a
1	24.238 ± 0.604a	24.035 ± 0.204a	23.695 ± 0.296a	11.067 ± 11.075a	2.512 ± 2.294a	1.652 ± 0.392a
1.5	18.716 ± 8.918a	24.057 ± 0.079a	19.192 ± 7.804a	20.391 ± 4.079a	8.034 ± 12.152a	2.761 ± 1.592a
2	23.831 ± 0.068a	23.854 ± 0.104a	17.132 ± 10.195a	10.637 ± 11.613a	4.096 ± 5.273a	6.767 ± 7.211a

Values of runoff for a certain DAS measurement followed by same lowercase letter (column) were not significantly different ($P < 0.05$)

On the other hand, research plots with drainage canal treatments (R1, R1.5, and R2) gave higher total and average values of runoff ranged 86.317 – 93.151 and 14.386 – 15.525 m^3 ha^{-1}, respectively (Figure 5). The total runoff was the total number of runoff during the whole time span of cultivation, while the average runoff was the average of 6 measurements conducted namely measurements at 35, 43, 49, 56, 63, and 71 DAS (Figure 4). This result might imply that the existing drainage canal may promote a more surface runoff occurrence. In this case, rainwater might take drainage canal as a passage to flow, and thus, there would be less time becomes for rainwater to infiltrate into the soil. Consequently, rainwater would flow and form surface runoff rather than infiltrating into the soil and develop water logging condition. At this stage, it is reasonable to think that establishment of drainage canal at a horizontal-ridge system is expectable for suppression of water logging condition.

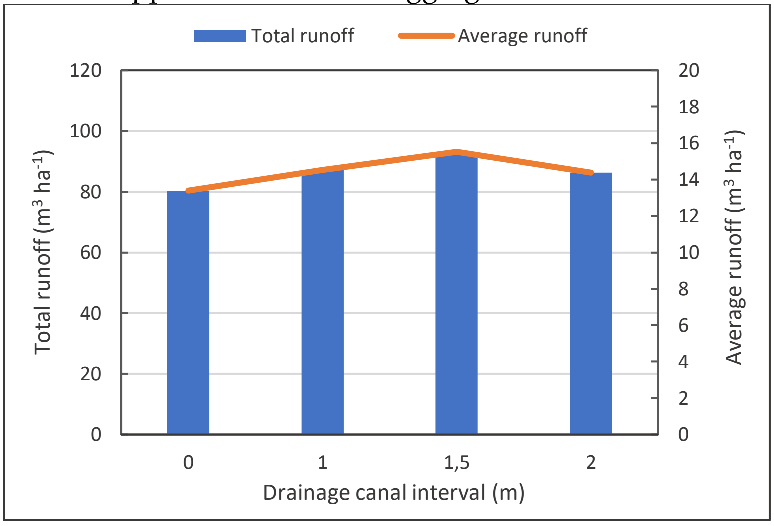

Figure 5. Total and average values of runoff according to the applied drainage canal interval

Other than these if we take a look deeper to the data shown in Figure 5, research plot R1.5 gave the highest total and average values of runoff as of 93.151 and 15.525 m^3 ha^{-1}, respectively (Figure 5). These values were even greater than that of the research plot R1 as of 87.199 and 14.533 m^3 ha^{-1}, respectively, regardless the higher number of existing drainage canals in research plot R1 (12 canals) than that of research plot R1.5 (7 canals). This result might imply that the number of existing drainage canal was not the sole factor for the runoff occurrence. This higher runoff in the latter was thought attributable to the higher value of dry bulk density than that of the former (Figure 3). Such a higher dry bulk density might indicate a more compacted soil structure, which in turn, may lead into a lesser rainwater infiltration but a higher surface run off occurrence. Conversely, lesser dry bulk density of the former might suggest a looser soil structure, by which rainwater become more easily infiltrate into the soil, and thus, a lesser surface runoff resulted.

In accordance with these, Ullyta et al (2022) and Wijaya, Kuncoro, et al (2020) have mentioned that compacted soil (indicated by a higher dry bulk density) resulted less infiltration, and thus, an increase of surface runoff. While, Nurmi et al (2012) has mentioned that size and stability of soil pore structure is of importance for soil infiltration. In line with this, Kuncoro et al (2014b, 2014a) has reported that an increased soil dry bulk density could be followed by reductions in soil total porosity and water movement, for which the reductions were more attributable to the reduced macropore volume. Further, soil with higher dry bulk density has been shown to having fewer continuous macropores for water movement in that study.

Soil loss

Similar to the result of surface runoff (Figure 4), volume of soil loss varied along the experimental period (0.002 to 0.507 ton ha^{-1}), and there was no certain patterns observed amongst the applied drainage canal interval treatments (Figure 6). Likewise, the applied drainage canal intervals gave no statistical significant differences for the whole measurements conducted (Table 3). However, it could be yet inferred from Figure 6 for an existence of positive correlation between the volume of rainfall and the volume of soil loss namely the eroded soil likewise. This result might support the knowledge that rainfall is the major driving force for the occurrence of soil erosion (Naharuddin, 2021; Panjaitan & Rusli, 2012). Moreover, scattering pattern of soil loss data shown in Figure 6 was similar to the scattering pattern of surface runoff data shown in Figure 4. This might also suggest a positive correlation between the volume of surface runoff and the entailing volume of soil loss (Henny et al., 2011; Ropiyanto et al., 2022).

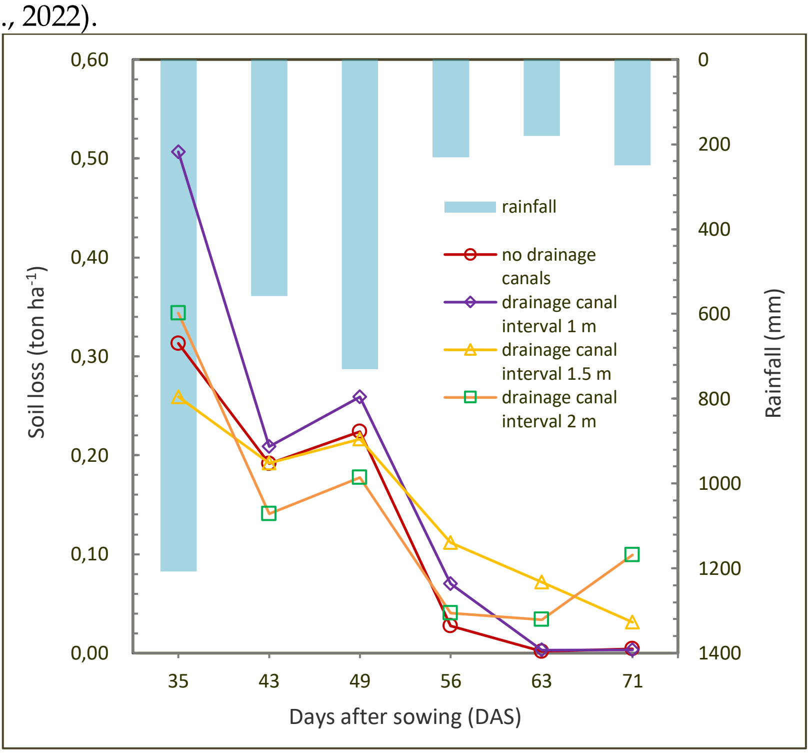

Figure 6. Soil loss variability along the observation period

Table 3. Values of soil loss along the observation period

Drainage canal interval (m)	Soil loss (ton ha^{-1})					
	35 DAS	43 DAS	49 DAS	56 DAS	63 DAS	71 DAS
0	0.313 ± 0.087a	0.191 ± 0.049a	0.224 ± 0.138a	0.027 ± 0.042a	0.002 ± 0.001a	0.004 ± 0.002a
1	0.507 ± 0.273a	0.209 ± 0.136a	0.259 ± 0.094a	0.070 ± 0.094a	0.003 ± 0.002a	0.003 ± 0.002a
1.5	0.259 ± 0.155a	0.192 ± 0.219a	0.216 ± 0.165a	0.112 ± 0.152a	0.071 ± 0.119a	0.031 ± 0.043a
2	0.344 ± 0.149a	0.141 ± 0.049a	0.177 ± 0.136a	0.040 ± 0.042a	0.034 ± 0.055a	0.099 ± 0.134a

Values of soil loss for a certain DAS measurement followed by same lowercase letter (column) were not significantly different ($P < 0.05$)

Comparing between research plot without drainage canal treatment (R0 and research plots with drainage canal treatments (R1, R1.5, and R2), the latter gave higher total and average values of soil losses than the former (Figure 7). This result might suggest that the existing drainage canal in a horizontal-ridge system may cause an increase of soil loss occurrence. In this case, the lowest values were found for research plot R0 as of 0.762 and 0.127 ton ha^{-1}, respectively. If we take a look closer to the results amongst the research plots with drainage canals treatments (R1, R1.5, and R2), the highest total and average values of soil losses were found for research plot R1 as of 1.051 and 0.175 ton ha^{-1}, and then followed by research plot R1.5 as of 0.881 and 0.147 ton ha^{-1} and research plot R2 as of 0.835 and 0.139 ton ha^{-1}. These results suggested that a greater drainage canal interval namely a lesser number of existing drainage canal would give a lessen soil loss.

In general, data of total and average soil losses shown in Figure 7 had a sufficient conformity to the data of total and average surface runoff shown in Figure 5 despite a slight discrepancy on the data of research plots R1 and R1.5. In Figure 7, research plot R1 gave higher values of total and average soil loss than that of research plot R1.5. In Figure 5, conversely, research plot R1 gave lower values of total and average surface runoff than that of research plot R1.5. This result gave insight that a lower runoff of research plot R1 (Figure 5) may yet result a higher soil loss (Figure 7), and vice versa.

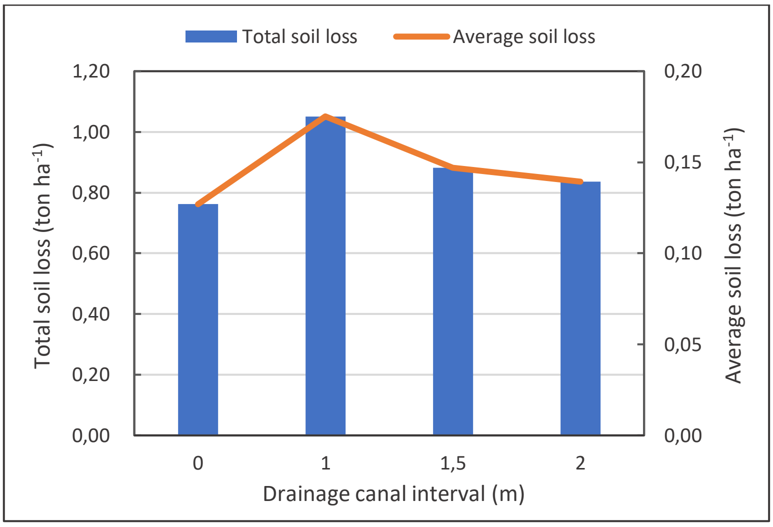

Figure 7. Total and average values of soil loss according to the applied drainage canal interval

This particular phenomenon was thought ascribed to the soil structure condition, which could be inferred from the data of soil dry bulk density shown in Figure 3. Comparing the results of research plot R1 to that of research plot R1.5, a looser soil structure of the former as inferred from the lower dry bulk density (Figure 3) was yet capable of promoting a more soil loss (Figure 7) despite of the lower surface runoff (Figure 5). Soil with such a loose structure becomes fragile and prone to disruption by rain splash and surface runoff erosion. Naharuddin (2020) has mentioned that soil erosion by rainwater takes place as a combination of 2 main process namely soil particle dispersion by rain splash and conveyance of those dispersed soil granules by the surface runoff.

Soil nutrient loss

The observed variability of N-total and P-total losses was presented in Figure 8 and Figure 10, respectively. The value of N-total loss ranged from 0.849 to 204.881 kg ha^{-1}, while the value of P-total loss ranged from 0.685 to 176.505 kg ha^{-1}. The data, however, had no statistical significant differences amongst the applied drainage canal intervals as shown in Table 4 and Table 5, respectively. If we take comparisons between N-total and P-total losses, each of drainage canals treatments (R0, R1, R1.5, and R2) had the same shape of data scattering as shown in Figure 8 and Figure 10. If we take comparisons amongst drainage canals treatments (R0, R1, R1.5, and R2), however, there was no certain trends noticed for both N-total and P-total losses, and it was yet difficult to determine the best and the worst treatments either. For instance, R1 and R1.5 treatments gave the highest and the lowest N-total losses at 35 DAS, respectively, but this was conversely at 63 DAS (Figure 8). This was also the case for P-total losses as shown in Figure 10.

Interestingly, it could be seen from Figure 8 and Figure 10 that the losses values of N-total and P-total tended to decrease as the rainfall diminished. This result was further supported by the data of runoff, particularly at 63 DAS measurements (Figure 4). Adding to this, data trend of soil losses (Figure 6) gave more sufficient congruence particularly at 35 and 63 DAS measurements. This suggested that the bigger volume of soil loss is the greater N-total and P-total losses become. These results were in a good agreement with the result of other previous studies (Henny et al., 2011; Wijaya et al., 2019; Wijaya, Masrukhi, et al., 2020) that soil nutrient loss has a direct correlation to the number of eroded soil, besides it also appears as the function of C-organic and nutrient concentrations in the soil sediment collected.

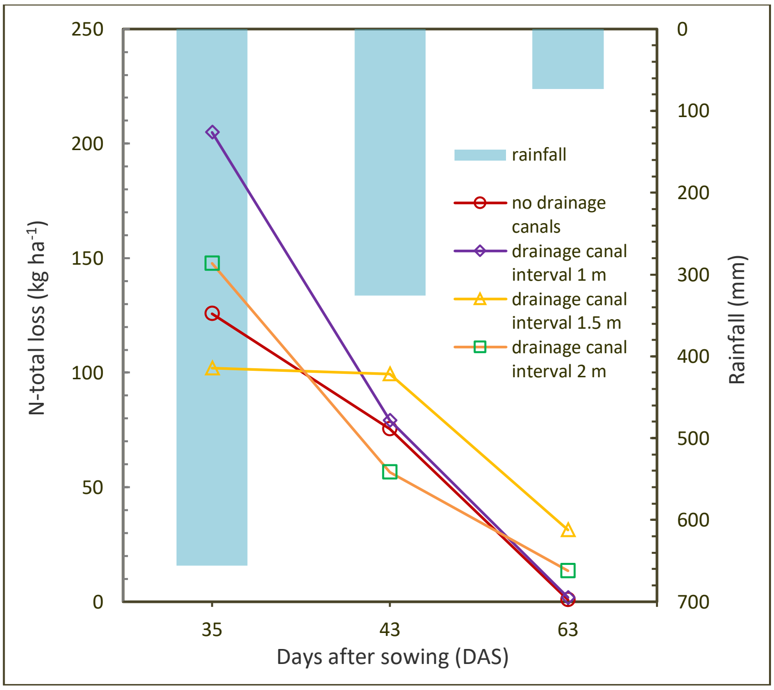

Figure 8. Variability of N-total loss observed

Table 4. Values of measured N-total loss

Drainage canal interval (m)	N-total loss (kg ha^{-1})		
	35 DAS	43 DAS	63 DAS
0	125.706 ± 41.991a	75.418 ± 18.141a	0.849 ± 0.345a
1	204.881 ± 115.01a	79.176 ± 41.120a	1.887 ± 0.992a
1.5	101.986 ± 63.346a	99.514 ± 91.159a	31.341 ± 51.997a
2	147.718 ± 68.565a	56.434 ± 18.770a	13.518 ± 21.796a

Values of N-total loss for a certain DAS measurement followed by same lowercase letter (column) were not significantly different ($P < 0.05$)

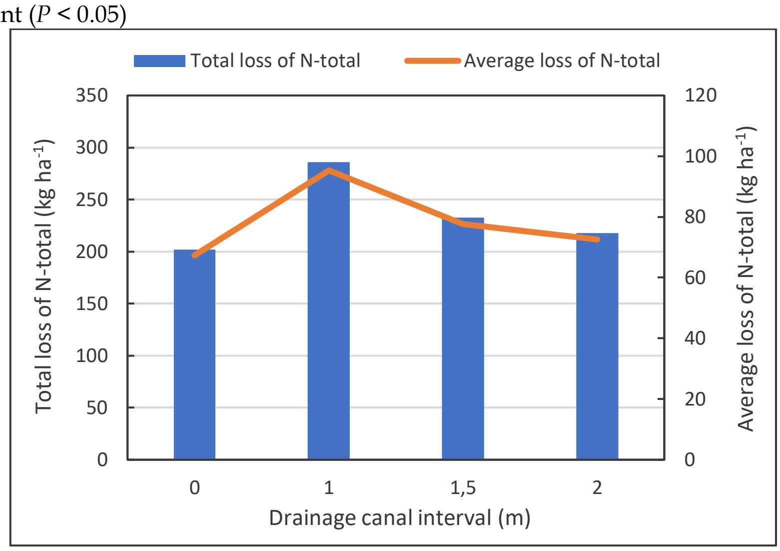

Figure 9. Total and average values of N-total loss according to the applied drainage canal interval

If we pay more attention to the total and average values of N-total and P-total losses, both of them had the same trends (Figure 9 and Figure 11). Compared to the research plot without drainage canal treatment (R0), research plots with drainage canal treatments (R1, R1.5, and R2) had higher total and average values of N-total and P-total losses. The highest total and average values of N-total losses were found for research plot R1 as of 285.944 and 95.315 kg ha^{-1}, and then followed by research plot R1.5 as of 232.841 and 77.614 kg ha^{-1}, research plot R2 as of 217.670 and 72.557 kg ha^{-1}, and the lowest value for research plot R0 as of 201.973 and 67.324 kg ha^{-1} (Figure 9). Likewise, the highest total and average values of P-total losses were found for research plot R1 as of 250.960 and 83.653 kg ha^{-1}, and then followed by research plot R1.5 as of 194.528 and 64.843 kg ha^{-1}, research plot R2 as of 180.044 and 60.015 kg ha^{-1}, and the lowest value for research plot R0 as of 170.931 and 56.977 kg ha^{-1} (Figure 11).

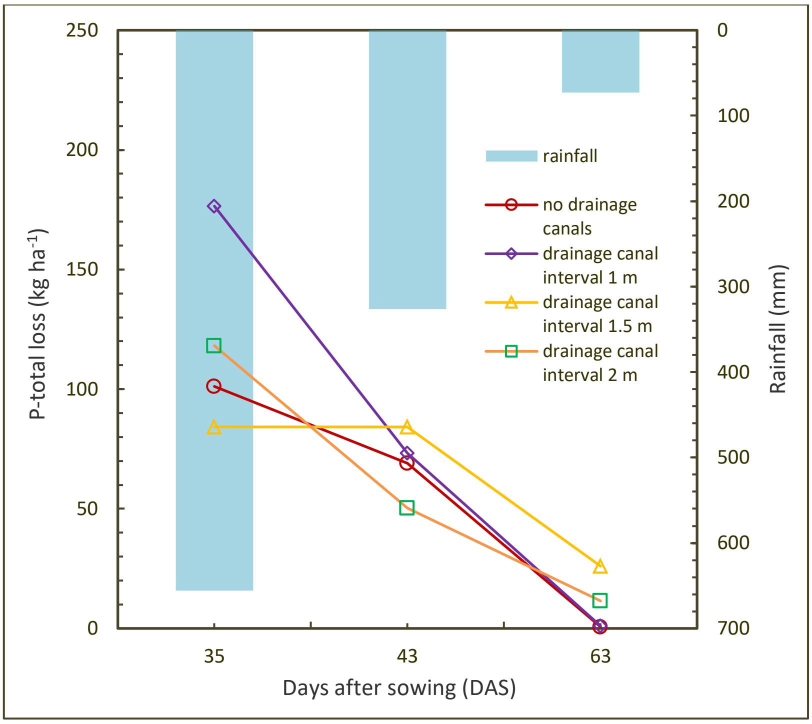

Figure 10. Variability of P-total loss observed

Table 5. Values of measured P-total loss

Drainage canal interval (m)	P-total loss (kg ha^{-1})		
	35 DAS	43 DAS	63 DAS
0	101.138 ± 39.548a	69.107 ± 19.090a	0.685 ± 0.354a
1	176.505 ± 91.308a	73.396 ± 44.554a	1.059 ± 0.594a
1.5	84.247 ± 53.030a	84.228 ± 79.281a	26.052 ± 43.285a
2	118.155 ± 39.003a	50.382 ± 16.544a	11.506 ± 18.421a

Values of P-total loss for a certain DAS measurement followed by same lowercase letter (column) were not significantly different ($P < 0.05$)

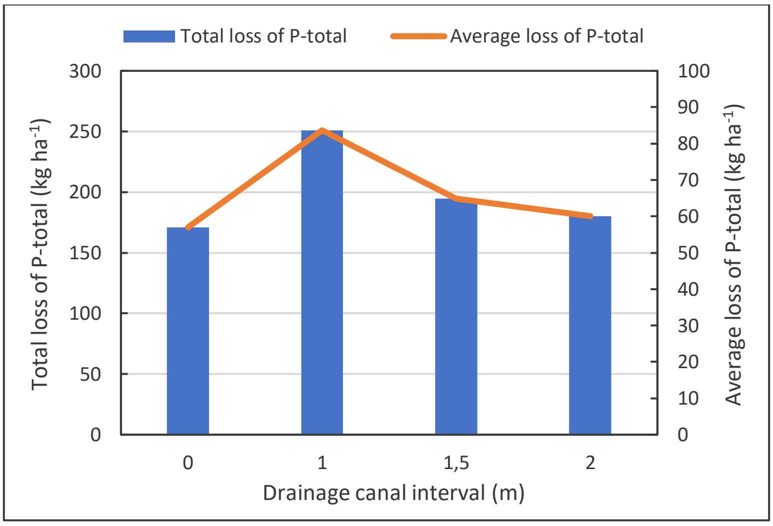

Figure 11. Total and average values of P-total loss according to the applied drainage canal interval

These results might suggest that the existence of drainage canal in a horizontal-ridge system may cause an increase of N-total and P-total losses. Adding to this, a greater drainage canal interval namely a lesser number of existing drainage canal for a certain area would give a lessen loss of both N-total and P-total. Interestingly, these results had a sufficient conformity to the values of runoff shown in Figure 5 and the values of soil losses shown in Figure 7. Thus, it could be inferred that the volume of runoff will affect the volume of soil loss, and the volume of soil loss will affect the both volumes of N-total and P-total losses.

Overall, results from this study revealed that drainage canals development at a horizontal-ridge system of potato cropping field might stimulate surface runoff occurrence. Thus, it became expectable for rainwater to take drainage canals as a passage to flow and form surface runoff rather than infiltrating into the soil and developing water logging condition. However, this runoff establishment was yet accompanied by the occurrence of soil and nutrient losses. Other than this, results of this study also confirmed the role of soil structure condition (compact or loose) on runoff and the entailing soil and nutrient losses. Compact structured soil may lessen rainwater infiltration and increase runoff. While, loose structured soil may increase rainwater infiltration and lessen runoff, but it is prone to erosion.

CONCLUSION AND SUGGESTION

Conclusion

The measured surface runoff, soil loss, N-total loss, and P-total loss ranged 24.714 – 0.951 m^3 ha^{-1}, 0.002 – 0.507 ton ha^{-1}, 0.849 – 204.881 kg ha^{-1}, and 0.685 – 176.505 kg ha^{-1}, respectively. The results revealed that existence of drainage canals at a horizontal-ridge system increased runoff. This meant rainwater may take drainage canals as a passage to flow and form runoff rather than infiltrating into soil and developing water logging condition. However, there were soil and nutrient (N-total and P-total) losses accompanying the runoff. Drainage canal interval 1 m (R1) gave the highest soil and nutrient losses followed by drainage canal interval 1.5 m (R1.5), drainage canal interval 2 m, and drainage canal interval 0 m (R0) as the lowest. This was thought attributable to the difference in number of existing drainage canal: 12, 7, 5, and 0, respectively. It was also noticeable for a sufficient trend conformity of the measured nutrient loss to the data of soil loss, runoff, and rainfall within a positive correlation amongst them.

Suggestion

Potato crop growth and yield should be taken into account in further study for determining the most ideal drainage canal interval for an optimum potato crop growth and yield within least occurrence of soil erosion.

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CONFLICT OF INTEREST

The authors declare that there is no conflicts of interest with any parties. Further, party with sponsorship for this research had no roles in research design, data collection and analysis, manuscript writing, and decision to the publication of research results.

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