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Research Article

The potential of intercropping of *Crotalaria juncea* on the reduction of Pb accumulation in *Brassica rapa* and *Phaseolus vulgaris* grown on Pb-contaminated soil

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Abstract

Many factors cause increasing Pb contamination in soils, including intensive crop production, motor vehicle exhaust gas around agricultural land areas, or irrigation mixed with household. An effort is needed to minimize Pb contamination in soils. This experiment aimed to examine the potential of *Crotalaria juncea* L. intercropped for minimizing the accumulation of Pb in vegetable crops grown using agrochemicals. The treatments tested were monoculture of *Brassica rapa*, monoculture of *Phaseolus vulgaris*, monoculture of *C. juncea*, intercropping *C. juncea* with *B.rapa*, and intercropping *C. juncea* with *P. vulgaris*. Results of the study showed that planting of *C. juncea* reduced the total dry weight of *B. rapa* by 33.47% and increased the total dry weight of *P. vulgaris* by 17.41% compared to monoculture. Intercropping of *B rapa* or *P. vulgaris* with *C. juncea* reduced the total Pb concentration of *B. rapa* by 45.64% and that of *P. vulgaris* by 16.22%. Planting of *C. juncea* reduced the Pb concentration in *B. rapa* by 21.23% (Pb 0.89 mg kg^{-1}) and that in *P. vulgaris* by 76.03% (Pb 0.93 mg kg^{-1}). Monoculture planting of *C. juncea* and intercropping of *C. juncea* with *B. rapa* or *P. vulgaris* reduced the concentration of available Pb and total Pb in the soil to not detected value, compared to monoculture planting of *B. rapa* and *P. vulgaris.*

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Introduction

Intensive crop production cannot avoid the use of agrochemicals. Long-term use of agrochemicals may damage soil health and the environment due to residues deposited in the soil. Another contamination caused by the use of agrochemicals is heavy metal contamination, especially Pb. Rahayu et al. (2020) have taken samples on intensive agricultural land in the use of fertilizers and pesticides in the village of Wonorejo, Poncokusumo sub-district showing Pb contamination up to 10.4 mg kg^{-1}. Heavy metals contamination in agricultural lands increased as a result of industrial activities, fertilization and other intensive and excessive use of agrochemicals (Luo et al., 2009; Luo et al., 2011), as well as irrigation with wastewater (Arora et al., 2008).

Many people may not realize that anthropogenic activities also cause Pb contamination in vegetables. Rahayu et al. (2020) revealed that applying Pb-containing phosphate fertilizer increased Pb shoot concentration of Chinese cabbage by 14.86% and Pb concentration in roots by 30.59%, while the use of pesticides increased Pb levels of Chinese cabbage shoots by 231% compared to the control. One of the dangers of heavy metals is that heavy metals are nonbiodegradable, and excess accumulation of heavy metals in agricultural soils causes health risks (Azimi et al., 2017; Ametepey et al., 2018). Pb, Cd, Hg, and As are non-essential elements that cause mutagen and carcinogenic at a low level (Järup, 2003; Ali et al., 2019). The main pathway through which humans can be exposed to heavy metals is through the land-plant-food route. Plants grown in contaminated soils can absorb and accumulate metals through both roots and leaves, causing health problems when they are consumed by animals and humans (Bi et al., 2009; De Temmerman et al., 2009; Bi et al., 2018). There are many factors that cause increasing Pb contamination in soils and vegetables, including intensive crop production, motor vehicle exhaust gas around agricultural land areas, and irrigation mixed with household or industrial waste, so an effort is needed to minimize Pb contamination in soil and vegetables.

Soils contaminated with heavy metals can be chemically, physically, or biologically remediated. Physical and chemical treatments such as leaching and combustion can affect soil properties and damage biodiversity, which makes the soil cannot be used as a medium for plant growth (McGrath et al., 2002). Ghosh and Singh (2005) summarized that phytoextraction is a phytoremediation technology that is effective if soil contamination is limited to a depth of about 3 feet from the surface. This technique can be applied primarily to locations with low to moderate levels of contamination. Because farmers cannot stop planting vegetable crops during the phytoremediation process, it is necessary to develop agricultural cultivation techniques that can reduce the contamination of heavy metals in agricultural soils. One the cultivation technique is an agronomic practice of intercropping system in which metal accumulator plants were intercropped with agricultural crops. Wu et al. (2007) reported that intercropping of agricultural crops with metal accumulator plants could effectively remove heavy metals so that the cultivated crops can be harvested and consumed safely. Sustainability of agricultural production with safe food production from contaminated soils is necessary because of the increasingly limited agricultural lands and the time required for phytoremediation of metals in contaminated soils (Wei et al., 2011).

Intercropping system is an agronomic approach strategy that may be for minimizing heavy metal accumulation in plant and soils because it involves several plant species that can better explore soil volume and improves heterogeneity of pollutant distribution in agricultural soils (Sheoran et al., 2011). Yang et al. (2017) reported that intercropping in contaminated soil affected the distribution of metal uptake by one of the plants. *Brassica chinensis* grown on soil contaminated with 10, and 20 mg Cd kg^{-1} produced more shoot biomass and accumulated less Cd in the shoot when it was planted with *Brassica juncea* rather than planted in monoculture (Liu et al., 2007). Karamina et al. (2014) reported that *Crotalaria juice* that was planted around the *Aloe vera* in soil contaminated with Al (1747 mg kg^{-1}) and Pb (112.51 mg kg^{-1}) was able to absorb 2986.5 mg Al kg^{-1} and 4.73 mg Pb kg^{-1}. Similarly, *Crotalaria mucronata* that was grown around *Aloe vera* was able to absorb 1756 mg Al kg^{-1} and 4.29 mg Pb kg^{-1}. Planting management of Pb accumulator plants from legume groups such as Crotalaria in agronomic practices is expected to reduce Pb uptake by vegetable crops. However, there are limited studies that examine the *C. juncea* as a companion plant in a vegetable cropping system. Therefore this study aimed to examine the potential of *C. juncea* as a Pb accumulator plant in intercropping with vegetable crops to minimize the accumulation of Pb in vegetable crops and soil.

Materials and Methods

Description of the study area

The experiment was carried out in the horticultural land of Wonorejo Village, Poncokusumo District, Malang Regency of East Java. The planting area is an agricultural center for vegetable production that has been intensively using production inputs, both organic and agrochemicals (fertilizers and pesticides) for more than 10 years. The study area has an average temperature of 21.7 ºC and an average annual rainfall of around 2300-2500 mm. Soil characteristics at the experimental site are as follows: pH = 5.3, organic C = 0.26%, total-N = 0.06%, available P = 64.02 mg kg^{-1}, exchangeable K = 0.28 cmol kg^{-1}, exchangeable Mg = 0.3 cmol kg^{-1} , cation exchange capacity = 13.02 cmol kg^{-1}, base saturation = 53%, available Pb = 3.39 mg kg^{-1}, total Pb = 30.4 mg kg^{-1}, and loamy texture. Soil characteristics at the experimental site are as follows: pH = 5.3, organic-C = 0.26%, total-N = 0.06%, available P = 64.02 mg kg^{-1}, exchangeable K = 0.28 cmol kg^{-1}, exchangeable Mg = 0.3 cmol kg^{-1} , cation exchange capacity = 13.02 cmol kg^{-1}, base saturation = 53%, available Pb = 3.39 mg kg^{-1}, total Pb total = 30.4 mg kg^{-1}, and loamy texture.

Experimental design

The treatments tested were monoculture of *Brassica rapa* (P1), monoculture of *Phaseoulus vulgaris* (P2), monoculture of *Crotalaria juncea* (P3), intercropping of *Crotalaria juncea* with *Brassica rapa* (P4), and intercropping of *Crotalaria juncea* with *Phaseoulus vulgaris* (P5). Five treatments were arranged in a randomized block design with five replications. The experiment was carried out in the field with a plot size of 4.2 x 2.5 m for each treatment. In the monoculture cropping system, *P. vulgaris* seeds were planted with a planting space of 60 x 50 cm, *B. rapa* seeds were planted with a planting space of 60 x 50 cm, and *C. juncea* seedlings were planted with a planting space of 20 x 20 cm. In the intercropping system, the planting space for *P. vulgaris* was 60 x 50 cm, and the planting space for *B. rapa* was 60 x 50 cm. As the intercrop, *C. juncea* was planted with a planting space of 20 cm in rows and 50 cm between rows in the intercropping system, and the distance between *C. juncea* from vegetable crops was about 20-30 cm. Vegetable crop seedlings were obtained from agricultural shops in the vicinity of the study site, while *C. juncea* seeds were obtained from the Research Institute for Sweetener and Fiber Plants (Balittas), Malang, East Java. At the age of 1 week after planting, each treatment was supplied with 300 kg of phosphate fertilizer ha^{-1}, 300 kg Urea ha^{-1}, and 150 kg KCl ha^{-1}.

Data collection

At the age of 60 days after planting, the ten of sample plants from *B. rappa, P. vulgaris,* and *C. juncea* were harvested and measured their total dry biomass and Pb content in the shoots, roots, and edible parts. For *P. vulgaris*, the harvested plant organs were divided into roots, shoots and edible parts (fruit/pods); while those of *B. rappa* were divided into shoots (as edible parts, i.e. leaves or heads) and roots; and while those of *C. juncea* were divided into shoots (as edible parts for animal) and roots. The plant organs were washed with clean water and then rinsed with deionized water to remove surface dust and soil. After the fresh weight was recorded, the tissue was then oven-dried at 70 ºC for 48 hours and weighed (Liu et al., 2012). Pb content in plant tissue was analyzed by HNO_3 reagent using Atomic Absorption Spectrometer (Agricultural Research and Development Agency, 2012). Metal accumulation in plants was then calculated by multiplying plant biomass by metal concentrations (Xu et al., 2016). Soil chemical properties analyzed at harvest were soil pH (H_2O 1:1) with a pH meter, total N by the Kjeldahl method (Agricultural Research and Development Agency, 2012), available P (Bray and Kurtz, 1945), organic C (Walkley and Black, 1934), cation exchange capacity (NH_4OAC pH 7.0), and soil Pb content by extraction method with 25% HCl extractor, and 0.1N HCl for Pb dissolved soil using Atomic Absorption Spectrometer (Agricultural Research and Development Agency, 2012). The ability of the plant to transport heavy metals from soil into edible parts of plants can be determined using Accumulation Factor (AF) (Li et al., 2012). The Accumulation Factor (AF) value was calculated based on the concentration of Pb in the edible part of vegetable plants divided by the concentration of Pb in the soil (Khan et al., 2013; Balkhair and Ashraf, 2016), as shown in the following equation:

$$AF = \frac{\text{[Pb] in the edible part of the plant}}{\text{[Pb] in contaminated soil}}$$

where [Pb] = Pb concentration in edible parts of plants or contaminated soil (mg Pb kg^{-1} of dry weight). Li et al. (2012) revealed that AF value > 1 is in the high category. Other sources revealed that the metal accumulation factor value >1 is high, 0.1>AF>1 is in the medium category, 0.1>AF>0.001 is in a low category, and <0.001 is known as non-accumulator (Malayeri et al., 2008; Wei et al., 2008; Rehman et al., 2017).

Data analysis

The data of plant biomass obtained were subjected to analysis of variance (ANOVA) of a one-way factor with the ANOVA table for randomized blocked design, followed by the orthogonal contrast test at a 5% level. The data of Pb concentration in plant tissues obtained were then used to calculate Pb accumulation and AF values. The data of plant Pb concentrations, Pb accumulation and AF values were then analyzed based on standard error difference (s.e.d) at the 5% level to determine the effect and differences in the results of each treatment.

Results

Plant biomass

The intercropping of *C. juncea* reduced the total dry weight of *B. rapa* by 33.47% and increased the total dry weight of *P. vulgaris* by 17.41% compared to monoculture (Table 1). The results of this study were in line with that of Lal et al. (2019), who tested intercropping between mustard and chickpeas. *C. juncea,* which was planted on the edge and middle rows of the intercropping system, acted as a border for *B. rapa*. In the row of the intercropping system, borderlines from higher plants increase yields while shorter crop sequences have lower yields (Li et al., 2013). Planting of *C. juncea* increased total *P. vulgaris* biomass by 17.41% compared to monoculture. The growth of the spreading *P. vulgaris* with the help of a stake could use the sun radiation freely, so it was not affected by the growth of *C. juncea,* which both grew upright in one planting location.

Pb concentration in plant

Total Pb concentration per plant in *B. rapa*, *P. vulgaris*, and *C. juncea* planted in monoculture were higher than those planted in intercropping (Table 2). Pb concentration in the edible parts of vegetable crops intercropped with *C. juncea* decreased by 21.23% and 76.03% for *B. rapa* and *P. vulgaris*, respectively, compared to that in monoculture (Table 2). Table 2 shows that Pb concentrations in *B. rapa* shoot (0.89 mg kg^{-1}) and *P. vulgaris* pod (0.93 mg kg^{-1}) slightly exceeded the Indonesian National Standard (SNI) threshold value for Pb of 0.5 mg kg^{-1}. This was due to the continuous use of fertilizers and pesticides containing Pb. Therefore, to minimize Pb uptake in vegetables, planting of *C. juncea* can be done repeatedly and alternative studies are needed further with the use of fertilizers and pesticides containing low Pb combined with *C. juncea* through other cropping patterns, including crop rotation. Data presented in Table 2 show that *C. juncea* could reduce Pb concentration in Pb-contaminated soil until the Pb content was not detected at the end of the plant harvest.

Table 1. Dry weights of *B. rapa*, *P.vulgaris*, and *C. juncea* in the monoculture and intercropping systems at eight weeks after planting.

Treatments		**Total dry weight (g plant^{-1})**
Vegetable crops	**Cropping system**	
B. rapa	Monoculture (P1)	106.28 b
	Intercropping with *C. juncea* (P4)	70.71 a
	Orthogonal contrast test	$p<0.05$
P. vulgaris	Monoculture (P2)	66.98 a
	Intercropping with *C. juncea* (P5)	81.10 b
	Orthogonal contrast test	$p<0.05$
C. juncea	Monoculture (P3)	55.83 b
	Intercropping with *B. rapa* (P4)	40.33 a
	Intercropping with *P. vulgaris* (P5)	30.40 a
	Orthogonal contrast test	$p<0.05$

Note: Numbers followed by different letters in the same plant species show significant differences based on the orthogonal contrast test at a 5% level.

Table 2. Pb concentration in the plant, Pb concentration in the edible parts, and Pb accumulation in the edible parts of *B. rapa*, *P.vulgaris*, and *C. juncea* in the monoculture and intercropping systems at eight weeks after planting.

Treatments		**Pb concentration (mg kg^{-1})**		**Pb accumulation in the edible parts of the plant (mg DW^{-1})**
Vegetable crops	**Cropping system**	**in the plant**	**in the edible parts of the plant**	
B. rapa	Monoculture (P1)	9.75 b	1.13 b	0.02 a
	Intercropping with *C. juncea* (P4)	5.31 a	0.89 a	0.02 a
	s.e.d	0.29	0.04	0.01
P. vulgaris	Monoculture (P2)	9.80 b	3.88 b	0.15 b
	Intercropping with *C. juncea* (P5)	8.21 a	0.93 a	0.04 a
	s.e.d	0.52	0.32	0.06
C. juncea	Monoculture (P3)	4.29 c	2.04 a	0.10 b
	Intercropping with *B. rapa* (P4)	3.21 a	2.07 a	0.07 a
	Intercropping with *P.vulgaris* (P5)	4.00 b	2.72 b	0.07 a
	s.e.d	0.10	0.07	0.002

Note: Numbers followed by different letters in the same plant species show significant differences at $p<0.05$ based on the standard error of difference (s.e.d).

Table 3. Soil chemical characteristics in monoculture and intercropping treatments between *B. rapa*, *P. vulgaris,* and *C. juncea* after planting for eight weeks.

Treatments	**pH H_2O**	**Organic C (%)**	**Total N (%)**	**P (ppm)**	**K**	**Na**	**Ca**	**Mg**	**CEC**	**BS (%)**	**Total Pb (ppm)**
					…………..(cmol kg^{-1})………….						
P1 (S)	6.5	0.80	0.10	59.02	0.54	0.30	6.60	2.09	21.38	45	1,17
P2 (B)	6.1	0.79	0.11	48.54	0.46	0.31	7.39	2.20	20.88	50	2.45
P3 (C)	6.0	0.80	0.09	53.99	0.28	0.28	6.24	3.04	20.05	49	nd
P4 (S+C)	6.0	0.71	0.11	49.26	0.40	0.30	7.66	2.07	22.36	47	nd
P5 (B+C)	5.9	1.13	0.09	58.62	0.43	0.30	7.79	0.78	20.69	45	nd

Note: nd = not detected, P1 (S) = *B. rapa* monoculture, P2 (B) = *P. vulgaris* monoculture, P3 (C) = *C. juncea* monoculture, P4 (S+C) = intercropping of *B. rapa* + *C. juncea,* P5 (B+C) = intercropping of *P. vulgaris* + *C. juncea,* CEC = cation exchange capacity, BS = base saturation.

Accumulation Factor (AF) of Pb

Table 4 shows that *C. juncea* and *P. vulgaris* planted in monoculture and intercropping systems produced a medium category Accumulation Factor (AF) value (0.1<AF<1). On the other hand, *P. vulgaris* intercropped with *C. juncea* and *B. rapa* planted in monoculture or intercropping produced a low Accumulation Factor value (AF <0.1).

Table 4. Accumulation Factor value of *B. rapa*, *P.vulgaris*, and *C. juncea* in the monoculture and intercropping systems

Treatments		**Accumulation Factor Value**
Vegetable crops	**Cropping system**	
B. rapa	Monoculture (P1)	0.04 a
	Intercropping with *C. juncea* (P4)	0.03 a
	s.e.d	0.01
P. vulgaris	Monoculture (P2)	0.13 b
	Intercropping with *C. juncea* (P5)	0.03 a
	s.e.d	0.06
C. juncea	Monoculture (P3)	0.07 a
	Intercropping with *B. rapa*(P4)	0.07 a
	Intercropping with *P.vulgaris* (P5)	0.09 b
	s.e.d	0.002

Note: Numbers followed by different letters in the same plant species show significant differences at $p<0.05$ based on the standard error of difference (s.e.d).

Discussion

Planting of *C. juncea* reduced the total Pb concentration in *B. rapa* by 45.64% and in *P. vulgaris* by 16.22%. *Planting of C. juncea* in intercropping with *B. rapa* allowed shading in the upper part of the plant so that pesticide spray containing Pb did not directly affect *B .rapa*. Planting of *C. juncea* in intercropping with *P. vulgaris* slightly decreased Pb concentration in *P. vulgaris* because of Pb uptake from the soil or Pb uptake due to foliar pesticide. Besides, *P. vulgaris* and *C. juncea* grow upright and spread upward so that the surface of the upper part of the plant is more directly exposed. Zhuang et al. (2009) revealed that the upper parts of leafy vegetables are more susceptible to physical contamination due to soil dust or splashes because the surface area of the top of plants has broader leaves. The accumulation of Pb and Cr in leafy vegetables resulting from metal deposition at the top of the plant is higher than the accumulation of Cd, Zn, Ni, and Cu, which are absorbed mostly from the root and followed by transfer to the shoots.

In general, vegetable crops can accumulate more heavy metals in the leaves, stems and fruit because of the close translocation distance (Li et al., 2010). An et al. (2011) reported that the rooting systems of plants grown in monoculture or intercropping could absorb large amounts of Cd, Pb, Cr, Cu, and Fe and then move the metals upward to accumulate in the shoots and fruits. Pb and Cr levels are often high enough to make crops unsafe. The concentration of Pb in plant parts varies between different vegetable plants, thus affecting the value of accumulation of Pb in plants (Bi et al., 2018), which may be related to the ability of each different plant and soil properties (Liu et al., 2013).

Pb concentration in the edible parts of vegetable crops intercropped with *C. juncea* decreased by 21.23% and 76.03% for *B. rapa* and *P. vulgaris*, respectively, compared to that in monoculture (Table 2). Tang et al. (2012) reviewed that intercropping has the potential to reduce the heavy metal content in plants. Intercropping may be able to change conditions together in the rhizosphere to affect the availability and sharing of metals for plants that grow close together. In monoculture planting, high Pb concentrations in *B. rapa* shoots and *P. vulgaris* pods were probably due to the absence of shade plants from the top so that pesticide foliar containing Pb could accumulate at the top of plants, including stems, leaves, and fruits. Zhuang et al. (2009) revealed that the upper leafy vegetables are more susceptible to physical contamination due to soil dust or splashes because the surface area of the top of plants has broader leaves.

The AF values of *B. rapa*, *P. vulgaris*, and *C. juncea* planted in monoculture and intercropping systems were included in the low to moderate category. Results of a study conducted by Zhuang et al. (2009) indicated that Pb transport in plants was the weakest among other metals; AF values of plants for several metals sequentially from the strongest were Cd>Zn>Cu>Pb. In intercropping system, the AF values of *B. rapa* (0.03) and *P.vulgaris* (0.03) were lower than that of *C. juncea* L. ($0.07\approx0.1$ and $0.09\approx0.1$). This indicates that in the intercropping system, Pb translocation in vegetable plants was lower than that in *C. juncea*. This was possible because *C. juncea* is one of the plants in the Fabaceae family, which belongs to the dicotyledonous plant family, which has taproots with a long and strong root tip, and develop lateral roots well and with lots (Orwa et al., 2009). Dicotyledonous plants are plants that can absorb Pb in the shoot higher than monocotyledonous plants (Chen et al., 2004). Besides, *C. juncea* is a cover crop that has upright growth with many branches at the top of the trunk (Mosjidis and Wang, 2011), so as a companion plant in intercropping, *C. juncea* can minimize the deposition of Pb metal in a foliar spray of pesticide on the vegetable plant.

Table 3 shows the concentration of available Pb in all monoculture plots, and intercropping at the end of the harvest was not detected. The total Pb concentration remaining in the soil after harvest found in *B. rapa* (P1) and *P. vulgaris* (P2) monoculture plots were 1.17 and 2.45 mg kg^{-1}, respectively. In the P3, P4 and P5 plots, the concentrations of total Pb in the soil at the end of harvest were not detected. In line with the study of Wan et al. (2017) on As-contaminated soil, intercropping can clean the soil even though phytoextraction may be lower, but achieving safe crop production at the same time is important in the remediation of soils.

In general, soil pH at harvest (after eight weeks of planting) in all monoculture and intercropping plots tended to be neutral. As reported by Gong et al. (2019), intercropping had little influence on soil pH. The results of this study showed that the pH in monocultures was slightly higher than that in intercropping. The soil organic-C contents in plots P1, P2, P3, and P4 were all very low; each value was below 1%, except for P5 plots of 1.13%. Soil organic C content in intercropping of *P. vulgaris* with *C. juncea* was greater than in *P. vulgaris* monoculture and *C. juncea* monoculture. This is in line with the results of research by Gong et al. (2019) that the intercropping pattern can affect soil properties, such as the increase of organic C content. The total N content of plots P1 (*B. rapa* monoculture), P2 (*P. vulgaris* monoculture), P3 (*C. juncea* monoculture), P4 (intercropping of *B. rapa*+*C. juncea*) and P5 (intercropping of *P. vulgaris*+*C. juncea*) ranged from 0.09% to 0.11%. The P contents in P1, P2, P3, P4, and P5 plots that ranged from 48.54 to 59.02 mg kg^{-1} were included in the very high category because the P contents were more than 15 mg.kg^{-1}. The soil K content in the P1, P2, P4, and P5 plots after planting for eight weeks showed a moderate category, ranging from 0.4 to 0.54 cmol kg^{-1}, except for the P3 plot (*C. juncea* monoculture) with low K content. Cation exchange capacity values in monoculture and intercropping plots ranged from 17 to 24 cmol kg^{-1}. Wang et al. (2015) reported that soil organic matter, total nitrogen, P, exchangeable K, and cation exchange capacity from intercropping of legumes (Faba beans) with corn did not differ from monocultures, except for the decrease of soil pH by 1.9%. The results of this study also showed that soil pH in the intercropping of *C. juncea*+*B. rapa* plot decreased by 7.69% and *C. juncea*+ *P. vulgaris* crop decreased by 3.28%. According to Li et al. (2016), the distribution and penetration of roots into the soil both in monoculture and intercropping systems can improve soil physical properties and soil structure. Interactions in the soil, for example, in the maize and peanut intercropping system, show an important role in changing the composition of soil microbes and the dominance of microbial species, which is strongly associated with improved soil nutrients, particularly N and P and on enzymatic activity. Root nodules formed by the roots of legume beans and *C. juncea* can make a large amount of contribution of N in the soil, thereby reducing nutritional competition in intercropping and, therefore, can increase nutrient uptake by plants (Gong et al., 2019).

Conclusion

Intercropping of *C. juncea* decreased Pb content in *B. rapa,* and *P. vulgaris* fed with pesticides and fertilizers containing Pb. Pb content in the edible parts of *B. rapa* and *P. vulgaris* intercropped with *C. juncea* decreased by 21.23% and 76.03% compared to monocultures. The accumulation of Pb in the stover of *C. juncea* intercropped with *B. rapa* and *P. vulgaris* was higher than that in the edible parts of *B. rapa* and *P. vulgaris*, as indicated by the higher Accumulation Factor value of *C. juncea* than *B. rapa* and *P. vulgaris*. Planting of *C. juncea* in monoculture and intercropping also reduced available Pb and total Pb contents in the soil compared to the monoculture of *B. rapa* and *P. vulgaris.*

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