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Distribution, Severity Status, Farmers Knowledge and Management Practices of Wild Radish (Raphanus raphanistrum L.) in Horro Guduru Wollega Zone, Western Ethiopia

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Abstract
The objective of the study was to study the distribution, severity status, farmers' knowledge, impacts and management practices of Wild Radish *(Raphanus raphanistrum L.)* in Horro Guduru Wollega Zone, Western Ethiopia. The collected data were analyzed by using descriptive statistics. The Shannon Diversity Index (SDI), the evenness, species richness and Jaccards Similarity Index (JSI) was calculated from the recorded weed samples. Correlation of vegetation variables among and between sampled Administrative Kebeles' was analyzed b***y*** SPSSv20 software. The result of the study indicates that out of the sampled 160 respondents 92 (57.5%) of them heard about wild radish plant as a weed and the rest of 68 (42.5%) of the respondents did not know this plant as a weed. Among the respondents 88 (55%) of them identify *R.raphanistrum* plant as a weed. There was high negative correlation between mean *R. raphanistrium* density and Shannon diversity index with $R^2 = 0.642$, $p<0.001$. This study showed that high infestation level of *R. raphanistrum* was observed in Horro district followed by Abayi Chomen, Amuru and Jima Rare districts. The highest and lowest mean population (±SD) of *R. raphanistrum* per quadrate was recorded at Horo (249.82 ± 34.67) and Jima Rare (13.72 ± 14.16), respectively. The biodiversity impact of *R. raphanistrium* at highly infested areas were more visible than the moderately infested areas. Horro and Abayi Chomen districts showed the lowest Shannon Diversity Index value of 1.78 and 2.12, respectively, due to the fact that, their species diversity was highly affected by the high population density of *R. raphanistrium.* Moreover, the standing herbaceous vegetation from the sampled sites of Horo district (Doyo Bariso and Gudina Abuna administrative kebeles) showed higher Jaccards Similarity coefficient (0.84), where there was high *R.raphanistrium* infestation level. The study proved that *R. raphanistrum* was emerged as invasive weed and have been disseminated into neighbor districts' and zones. Therefore, further research should be conducted to quantify the distribution, increases in species abundance as well as its impact on biodiversity and socio-economic aspects, which may support to contain *R. raphanistrum* distribution and planning on its prevention and management.
Keywords: Abundance, distribution, invasive*, Raphanus raphanistrum,* severity, wald radish
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1. INTRODUCTION

Wild radish, *Raphanus raphanistrum* L. (*Brassicaceae*), is one of the most invasive cosmopolitan world's worst agricultural weeds (Holm *et al*. 1997; Warwick & Francis 2005). Wild radish is in the *Brassicaceae* (mustard) family and the *Raphanus* genus (DIR139 2016; GRDC 2009; Sutherland 1999). Wild radish, *R. raphanistrum* is also known as white weed, jointed charlock, white charlock, wild charlock, wild kale, wild turnip, jointed radish and cadlock (Murrumbidgee, CMA, accessed July 2017). It has hermaphroditic, self-incompatible flowers pollinated by a variety of insects (Heather & Jeffrey 2007). *Raphanus* is derived from the Greek 'ra' (quickly) and 'phanomai' (to appear), which refers to rapid germination and growth of seedlings (Cheam & Code 1995). *R. raphanistrum* is considered to be among the worst weeds worldwide (Holm *et al*. 1997).

R. raphanistrum originates from Western Europe to central Asia and was introduced into Australia accidentally as a contaminant of agricultural produce in the middle of the 19th century. This plant has colonized North America, South America, Australia, Africa, and eastern Asia (Holm *et al*. 1997). It is the number one weeds in small grains, especially wheat in the southeastern US. Besides the US, it is also widespread in England, Kenya, and South Africa (Cheam 1986). It occurs in agricultural fields of small grains and forage crops, in waste areas, and sheltered beaches in many temperate areas of the world. Holm *et al*. (1997) and Warwick *et al.* (1999) reported that *R. raphanistrum* occurs in crops on a wide variety of soil types; sand clay, sandy loam chalky saline or rich nitrous soil but it has been reported acid sandy soils, Warwick & Francis (2005) indicated that *R. raphanistrum* may be thought of as an indicator plant that prefers acid sandy soil.

Seeds of *R. raphanistrum* dispersed by a number of agents, and are frequently a contaminant of commercial grain seed stocks. Seed may spread via agricultural produce (e.g. in grain and hay), human activity (footwear, machinery, and vehicles), livestock (hooves), wind and water (irrigation water and flood). After ingestion, seeds may also is able to pass unharmed through the gut of many animals including birds and cattle (Holm *et al*. 1997; Malik 2009).

Wild radish seeds commonly remain dormant (up to 70%) and viable in the soil for 6 to 15 years at depth in undisturbed soil (Madafiglio 2002; Newman 2003). It has the potential to be introduced accidentally in agricultural produce from many different sources as a contaminant of grain seed (Woolcock & Cousens 2000). Once established, this species invades disturbed habitats such as agricultural land, abandoned fields and roadsides (McGeoch *et al*. 2009). Moreover, it competes successfully with agricultural crops, has a long-lived seed bank and a rapid life cycle (Warwick & Francis 2005). *R. raphanistrum* life cycle ranged from 43.5 to 230.5 days. Plants emerged in the fall (seasons between summer and winter) had greater biomass production and seed production compared to once emerged in summer months (Singh 2009).

Wild radish produces up to 45,000 seeds m^{-2}. One plant in a wheat crop can produce 292 seeds and 52 plants m^{-2} can produce 17,275 seeds (Cheam & Code 1998). Singh (2009) reported that an average of 1,470 seeds plant^{-1} was produced when emergence occurred in July compared with an average of 10,170 seeds plant^{-1} when emergence occurred in November. Later emerging plants have a lower chance of setting viable seed and produce less seeds. It is also a prolific seed producer and can cause yield losses if not controlled in a timely manner (Singh 2009). Yield losses depend on wild radish density and time of emergence in relation to the crop. Densities as low as 10 wild radish plants m^{-2} reduced wheat yields by up to 20% (Reeves *et al*. 1981; Warwick & Francis 2005), with up to 50% reduction at densities of 80 wild radish plants m^{-2} (Hashem *et al*. 2001a). *R. raphanistrum* that emerges with the crop can cause more than 90% yield loss whereas populations that emerge more than 7 weeks later cause less than 20% yield loss (Blackshaw 2001). The allelopathic potential produced by this plant suppress the nearby growing cereal crop plants by emitting the allelochemical. Holm *et al.* (1997) also reported that ingestion of *R. raphanistrum* by sheep and cattle may taint milk and become health hazard (toxic substances due to erucic acid and glucosinolates content) and if bread wheat becomes contaminated with large quantities of *R. raphanistrum* seed, 'bread poisoning may result. Holm *et al*. (1997) reported that *R. raphanistrum* has been as weed of 45 crops in 65 countries.

Holm *et al*. (1991) on the Book of "World Weeds: Natural Histories and Distributions" mentioned the presence of *R. raphanistrum* at 'Say Ager at 9°N 39.5°E in Ethiopia. This book presents comprehensive and up-to-date information on over 100 weed, including those species responsible for a high proportion of the world's crop losses. At this time *R. raphanistrum* ('*gommanee'* in Afaan Oromoo) infested Horro Guduru Administrative zone of Oromia Regional State infested. Dechasa (2003) reported that *R. raphanistrum* was first detected in Horro district of Horro Guduru Wollega zone. Ravi *et al*. (2014) also stated that *R. raphanistrum* is one of the most widespread, damaging and difficult weeds to control but little studied weed in Ethiopia, particularly in Horo Guduro Wollega zone of Oromia Regional State, where it is common in cultivated crops. Information's obtained from Zone Agriculture Office reviled that the problem of *R. raphanistrum* last from 20 to 25 years and now its severity increases from year to year. The farmers experience some cultural practices such as hand weeding and slashing and herbicide spraying to reduce the damage caused by *R. raphanistrum*. However, neither of these practices is effective so far for the management of *R. raphanistrum* especially in cereal crops. Even though the farmers of the study area experienced some cultural practices and herbicide application, its distribution and severity status increases from year to year. Thus, the goal of this study was to investigate the distribution, colonization history and severity status of *R. raphanistrum* in Horro Guduru Wollega zone of Oromia Regional State. [1012 words; 13811 ÷ 1012 = 13.6%]

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted in Horro Guduru Wollega Administrative zone (HGWz) of Oromia Regional State (Figure 1). The zone town, Shambu, is located at 314 km west of Addis Ababa (Belay *et al*. 2015). The zone has a total population of 570,040 of whom 285,515 male and 284,525 were female (CSA 2007). From the zonal population 505,301 were rural dwellers, of which 252,474 and 252,827 were male and female, respectively. Among the rural people, 121,136 were households with an average of 4.71 family sizes. From the total population of the zone 64,739 or 11.36% are urban inhabitants. The two largest ethnic groups reported live in HGWz were the Oromo (86.12%) and the Amhara (13.34%), while other ethnic groups made 0.54% of the zone population. 'Afaann Oromoo' and 'Amharic' languages are spoken by 85.95% and 13.59%, respectively, while the remaining 0.46% of them spikes other languages as primary language. The majority of the inhabitants were Protestants, with 42.99% while 38.47% of the population professed Ethiopian Orthodox Christianity, 8.91% observed traditional beliefs (Wakefata) and 8.61% of the population were Muslim.

The study area is stratified into three agro ecological zones based on agro-climatic conditions namely; low land 7.86% (1000-1500 m), mid land 37.89% (1500-2300 m), and high land 54.75% (2301-2835m), with an average altitude of 2296 m.a.sl (Mekonnen *et al*. 2012). The zone town, Shambu, lies with geographical coordinates of 09º29´N and 37º26´E. The zone has one long rainy season characterized by unimodal distribution and extends from March to mid October with an average rainfall that ranges between 1000-2400 mm (Olana 2006). The monthly mean temperature varies from 14.9°C to 27°C. The area is favorable for multi disciplinary agricultural activities, livestock and fishery production. Farmers in Horo Guduru Wollega zone of Oromia state lead their livelihoods by mixed crop-livestock production system (Belay *et al*. 2015).

Mixed crop-livestock agriculture is the mainstay in the study area with notable food crops including wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), '*teff*' (*Eragrostis tef*), maize (Zea mays), pulses (*Vicia faba*, Pisum sativum) and cash crops like sesame (*Sesamum orientale*), niger (*Guizotia abyssinica*), linseed (*Linum usitatissimum*) and vegetables are the major crops grown in this zone (CSA 2016). Perennial crops such as coffee and fruit crops like mango, papaya and banana are also grown in the low land part of the zone. In areas having wetland management (bone farm), sugar cane cultivation is also habited by the rural people for home consumption and as additional cash income, which was lately adopted from the neighbor, Fincha Sugar Factory sugarcane plantation. In fact, HGWz is commonly known as one of the surplus producing zone of Oromiya Regional State. Small-scale farmers in the zone extensively use chemical fertilizers, improved seeds, herbicides and insecticides to maximize their crop production. With regard to live stock, HGWz is raring different live stock animals like bovine, ovine, equine and fowls from which the 'Horro Cattle' and 'Horro Sheep' known by their peculiar 'red color' and 'long-flat tailed' indigenous breed, respectively (http://en.wikipedia.org/w/index.php; Assessed 16 March 2017).

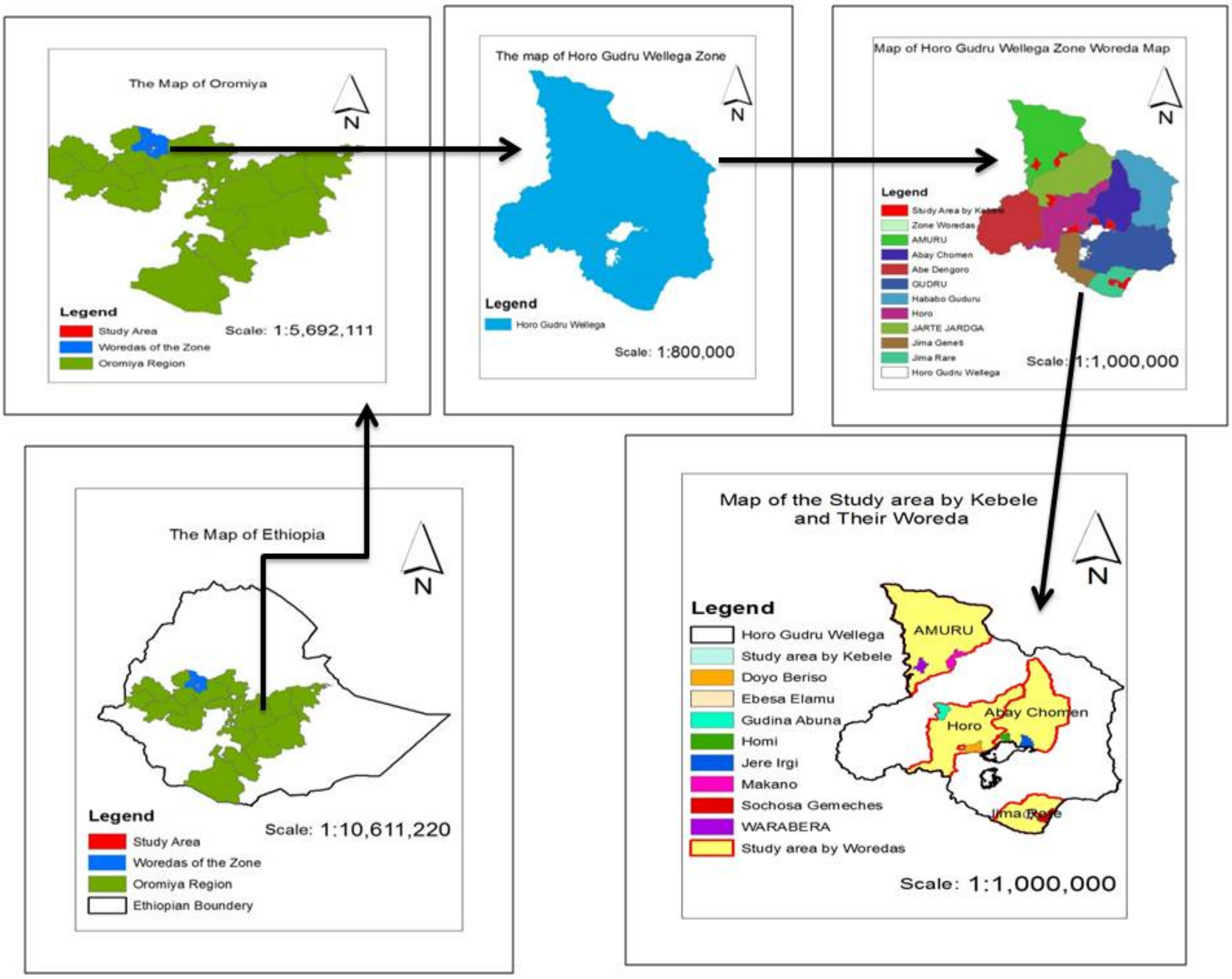

Figure 1.Wild Radish (*Raphanus raphanistrum*) Study Area Map

2.2. Method of data collection and sampling procedures

The study was conducted in 2016 from the month of June to December crop production season. In this study, four districts namely Horro (9°34′N37°06′E), Abay Chomen (9°54′N 37°27′E), Jima Rare (9°10′N 37°20′E), and Amuru (9°50′N 37°10′E), districts were selected purposively based on the existing crop types and crop production experience, their geographical location, their representativeness, expected to be affected by *R. raphanistrium* infestation and access for data collection. From four districts 8 (2 from each) administrative kebeles namely; Gudina Abuna & Doyo Bariso from Horro district, Homi & Jare from Abayi Chomen, Ibsa Ilamu & Sochosa Gamachisa from Jima Rare and Makano & Wara Bera from Amuru districts were selected for this study. Following Zahid *et al.* (2012) procedures, from each district two administrative kebele's and from each 20-farm households (totally 160 respondents) were selected for the intended study. Information about the introduction and occurrence of *R. raphanistrium*, weed infestation level, damage status, management practices and possible ways of weed dissemination mechanisms were collected from the respondents through interview questionnaire. Additionally at kebele level, focus group discussions having 10-15 members were implemented for brain storming and testing of farmers' knowledge on *R. raphanistrium*.

Based on the agro ecology of the study area, from each administrative kebele's three sites and 36 quadrates from each site were selected purposively and the degree of infestation of *R. raphanistrium* and other herbaceous weeds stand were record. Following Phil *et al*. (2004) procedure, GPS was used to locate the the coordinates of study area. Arc View GIS 3.2 software was used to map the study sites and the infestation area. Secondary data was collected from zone and district agricultural offices for additional information.

2.3 Data collection

2.3.1 Respondents knowledge on Wild Radish, R. raphanistrum

Information related to peoples‟ perception about the impact of *R. raphanistrum* in rural areas (both arable and non-arable lands) was collected from sampled study areas. A preliminary survey was conducted before the actual research work to test the actual distribution of the wild radish, *R. raphanistrum*. The survey was undertaken to observe the presence of different weed species, *R. raphanistrium* presence or not, the possible dispersal mechanisms, its invasiveness, its impact on crop yield, animal and human health. For interview questioner and semi-structured interview, 160 respondents (farmers) at the age range of 30 to 75 year were included. Equal number of respondents from each administrative kebeles' were identified and selected through purposive sampling procedure. The selection of the respondents was based on the awareness on the aggressive colonization of *R. raphanistrium* on arable land and non-arable land (roadsides) its impact on crop production, livestock and plant biodiversity. Furthermore, for additional information field observations, interview and focus group discussions were made with development agents and district agricultural experts.

2.3.2 Sampling method and sample size determination of R. raphanistrium and herbaceous weeds stand data

Wild Radish, *R. raphanistrium* and herbaceous vegetation samples were collected from 24 farmhouse holds. Field crops considered for data collection were cereals, pluses, and oil crops. Field crop types used for herbaceous weed sample collection were '*teff*'', wheat and maize for cereal crops; field pea and broad bean for pulse crops and noug for oil crops. Wittenberg *et al*. (2004) transect survey method was employed and a quadrate was laid at a distance of 50 m. For each sample plot of field crops, four sample quadrates were taken by laying a quadrate (1m x 1m) at a distance of ten meters and marked out (Kombiok *et al.* 2003). Weed vegetation stand data including *R. raphanistrium* were collected from 864 quadrates of 144 sample sites from six field crops of eight sampled administrative kebeles.

The majority of the plant species collected from the quadrates were identified in the field and recorded. The nomenclature of the rest of plant species were identified by using the Flora of Ethiopia and Eritrea (Hedberg & Edwards 1995) and by weed identification hand book of Naidu (2012). All herbaceous plants that are within the quadrate were identified in the field and counted. Subsequently, at every time of data collection the sample quadrates of crops in the two districts were weeded, the number of weeds per quadrate was counted, and the average was determined per quadrate.

In order to investigate the relative abundance and composition of the herbaceous vegetation as impacted by wild radish, *R. raphanistrium*, the proportion of individual species (cover and abundance of the plant species) encountered in each of the quadrates was recorded using the procedure documented by Wittenberg *et al*. (2004). This method involves a total estimate based on abundance and cover of the species where invasion is spatially patchy. The total estimate scale (abundance plus coverage) can be shown as follows. None of any plant species covers an area =0, plant species covers ≤ 5% area = 1, plant species covers 6 to 25% area = 2, plant species covers 26 to 50% area = 3, plant species covers 51 to 75% area = 4 and plant species covers 76 to 100% area = 5. Following the methods suggested by Chellamuthu *et al*. (2005), the sample sites were categorized into different groups based on percent area coverage of wild radish infestation levels: No wild radish infestation = 0%, very low level of infestation = ≤ 10%, low level of infestation = 11 to 25%, moderate level of infestation = 26 to 50% high level of level of infestation = 51 to 75% and very high level of infestation = 76 to 100%.

Diversity of the species for the vegetation data from the sample sites in the study areas were compared using Shannon Diversity Index. This index accounts both for the abundance and the evenness of the species in natural environment as shown by the equation below (Shannon and Wiener, 1949). It is also used to assess the impact of *R. raphanistrium* on the diversity of herbaceous plant species. The higher value of index of diversity indicates the variability in the type of species and heterogeneity in the community where as the lesser values point to the homogeneity in the community.

$$H = -\sum_{i=0}^{s} PiInPi \qquad (1)$$

Where H‟ = Shannon diversity index; P_i = the importance value of the $_i$th species; S = total number of species in the sample quadrate. The evenness of species 'E' was calculated as proposed by (Hill, 1973):

$$E = \frac{H^-}{In\, S} \qquad (2)$$

Where ‘E’ = evenness

This index explains how equally abundant each species would be in the plant community and high evenness is a sign of ecosystem health. This is because it does not have a single species dominating the ecosystem. The evenness or equitability assumes a value ‘0’ and ‘1’ with ‘1’ being complete evenness and ‘0’ a single species dominating the area. The similarity of the standing vegetation (herbaceous vegetation layer) among the sample sites in this study area was compared using Jaccard’s coefficient of similarity (JCS**)** as shown by the equation below. This coefficient of similarity has been recognized robust and unbiased compared with other similarity indices, even with small sample size (Ludwing & Reyonlds 1988).

$$JCS = \frac{a}{a+b+c+d+e+f} \qquad (3)$$

Where, JSC **=** Jaccard‟s Coefficient of Similarity; a = species common to quadrate 1,2,3,4,5 and 6; b = species present in quadrant 1 but absent in quadrate 2,3,4,5 & 6; c = species present in quadrate 1 but absent in 3,4,5 & 6; d = species present in quadrate 1 but absent in quadrate 2, 4, 5 & 6; e = species present in quadrate 1 but absent in quadrate 1, 2, 3, 4 & 6; f = species present in quadrate 1 but absent in quadrant 1, 2, 3, 4 & 6 and = species present in quadrate 6 but absent in quadrate 1, 2, 3, 4 & 5. The coefficient has a value from ‘0’ to ‘1’, where ‘1’ reveals complete similarity and ‘0’ complete dissimilarity.

2.4. Data Management and Analysis

Collected data were entered into MS Excel spreadsheet (Excel 2007) for clearance of data. Descriptive statistics and percentage were analyzed using Excel spread sheet and Statististical Program for Social Sciences (SPSS) Version-20 software. Chi-square was used to identify the level of significances between dependent and independent variables. Mean and standard deviation were used to analysis the wild radish and other weed species structure and distribution performance of the mentioned weed species. In all cases, the 95% confidence interval and the 5% level of significances can be used to declare the significant difference. The correlation of vegetation variables such as species composition, species richness, average *R. raphanistrium* density/sample, and average number of flower head/plant among sample sites were done to check if there is any association among and between sample sites.

3. RESULTS

3.1. Household Characteristics and demography

The householders’ education level, Age and sex, family size and household characteristics are indicated in Table 1. The householders’ education level, Age and sex, family size and household characteristics are indicated in table 1. It depicted 78.2% of the respondents had formal education; out of which 48% attended elementary education (1-4), 19.4% attended Junior Secondary School (5-8), 7.5% attended high school (9-12) and 2.5% were TVET graduates. In the current study, 95.63% of the family leaders were male while 4.37% household heads were females. This study also indicated the mean family size was found 6.46 person/households. Even though the households in the study area were mainly male headed, women play a significant role in weed management than their men counterparts. Very small numbers of young male households (< 40 years age) participate in weed management, which might be because, as socio-cultural norms of the rural community weed management is the farm activity expected from females and farming with an oxen or plougishing is the activity assigned for young men households. Farm households whose age above 70 years are on retirement from major agricultural activities except participating on supervision of farming activities and rendering guidance for the family members. Data obtained from the survey reviled that among 160 respondents 156 (97.5%) were married and four (2.5%) were widowed/divorced.

Table 1. Household (HH) characteristics: sex, age and level of education

Household (HH) characteristics	Frequency	Percent (%)
Sex		
Male	153	95.63
Female	7	4.37
Level of Education		
Informal Education	35	21.8
1 – 4	78	48.8
5 – 8	31	19.4
9 – 12	12	7.5
TVET	4	2.5
Age		
21 – 30	0	0-
31 – 40	8	5
41 – 50	44	27.5
51 – 60	70	43.75
61 – 70	32	20
71 – 80	6	3.75
80+	0	0
Marriage status		
Married	156	97.5
Un married	0	0
Divorced/widowed	4	2.5
Occupation		
Crop production only	0	0
Crop and Animal production (mixed)	160	100

3.2. Crop production and weed management practices in the study area

In the study area farmers' practices hand weeding, slashing and herbicide application for weed management. During field survey, some of crop fields were infested with different weed species (broad leaved and grassy weed species). The infested crop fields were crops of those elder people and poor families, which were in shortage of labor and resources. Most of the young peoples' that are at the active stage of production were migrated to nearby towns for search of high-level education and jobs. Due to these shortage of man power, older men and women including under aged children's were responsible for managing cultivated crops and live stock herding. Among 160 sampled respondents 123 (76.87%) of them used chemical herbicides for weed control.

3.3. Wild Radish Introduction to Horro Guduru Wollega zone (HGWz) and its Distribution

For the emergence of wild radish, the elders in the study area and the zone Agriculture and Natural Resource Office senior experts told two ideas. Information obtained from HGWz Agriculture and Natural Resource Office senior experts indicates that the introduction of wild radish for the first time observed in Horro district at Doyo Bariso kebele on experimental plot lands of Agricultural Research Station (1.25ha) which was owned by Bako Agricultural Research Center (BARC) since 1979. During farmers' field day, farmers who visit the field experiments on the station observe *R. raphanistrum* as ornamental plant and interested with the colors of the plant (yellow and white color) and they took the seed and seedlings to their home garden as an ornamental plant. After a few years, these peoples recognized it as this plant is dangerous weed plant rather than ornamental one. Another idea we come over for the introduction of *R. raphanistrum* was that this weed plant was introduced with infested cereal grains used for seed purposes. Interviewed two elder farmers who are residents of Doyo Bariso kebele mentioned that "the introduction of *R. raphanistrum* in to the locality was through cereal grain seeds introduced from other places (personal communication with Ato Shumbash Tesgera and Bayana Gabawa). The two elder men introduced wild radish unknowingly since 1986 with cereal grain seeds from their relatives. According to these two elders, suspicion for the introduction of this plant was by the owner of the research station, BARC, who brought different cereal grain seeds for experimental purposes during its stay at Doyo Bariso. The second idea for the introduction of *R. raphanistrum* was food aid grains introduction to their area during the 1990 drought and starvation, which was the case for the death of thousands and hunger for millions of the people in Ethiopia including HGWz the zone. Even though these two ideas were raised from different corners, there was no tangible information and responsible bodies for the introduction of wild radish, *R. raphanistrum* into the study area including the year of introduction.

3.4. Farmers knowledge on emergence and distribution of Wild Radish (R. raphanistrum)

Respondents' knowledge on emergence and distribution of wild radish (*R. raphanistrum*) in the study areas is depicted in (Table 2). According to the information obtained from the respondents, prior to 1979, the study area was free from *R. raphanistrum* infestation. Data obtained from the survey shows that most of field crops grown in the study area were infested by different common weed species including *R. raphanistrum*. The knowledge of the respondents on *R. raphanistrum* infestation on their farmland and homestead was tested whether their farmland and homestead is infested or not by this invasive weed. Data obtained from respondents' shows that out of the sampled 160 farmers 88 (55%) of them know *R. raphanistrum* as a weed on their farmland and homestead. The rest of 72 (45%) of respondents did not know this plant as a weed in their area and administrative kebeles'. Only respondents nearby Horro district and the near-by infested kebeles' have some information about the emergence of this invasive weed. From the sampled respondents 92 (57.5%) of them gave their idea as they know when did the *R. raphanistrum* infest their locality and 68 (42.5%) respondents do not know when did *R. raphanistrum* infest their locality.

Table 2. Farmers knowledge on emergence and distribution of wild radish (R. raphanistrum) in the study areas (N=160)

Study Parameters	Alternatives	Horro	A.Chom.	J/Rare	Amuru	Frequency	%
Have you ever heard about wild radish, *R. raphanistrum* weed?	Yes	40	40	19	13	112	70.0
	No	0	0	21	27	48	30.0
	Total	40	40	40	34	160	
Can you identify *R. raphanistrum* among other weed species?	Yes	40	40	12	8	100	62.5
	No	0	0	28	32	60	37.5
	Total	40	40	40	40	160	
Is your farmland infested by *R. raphanistrum*	Yes	40	40	12	8	100	62.5
	No	0	0	28	32	60	37.5
	Total	40	40	40	40	160	
Year of the 1st emergence of *R. raphanistrum* recognized by respondents in the study area	1979-1980	8	0	0	0	8	5.0
	1981-1985	6	0	0	0	6	3.75
	1986-2000	16	6	0	0	22	13.75
	2001-2005	4	10	0	0	14	8.75
	2006-2010	6	16	0	0	22	13.75
	2011-2015	0	8	12	8	28	17.5
	Un aware	0	0	28	32	60	37.5
	Total	40	40	40	40	160	

Key: A/Cho. = Abayi Chomen, J/Rare = Jima Rare

3.5. Extent of wild radish (*R. raphanistrum*) distribution, dispersal mechanisms, impacts and management methods employed

The extent of wild radish (*R. raphanistrum*) distribution, dispersal mechanisms, impacts and management methods employed by the sampled respondents are indicated in Table 3. According the results of data collected 50% of the respondents who are aware gave their idea, the wild radish extent of distribution in their area was high. The respondents declare grain seeds, food aid, animas, floods, farm implements and vehicles are mechanisms of weed seed dispersal in which grain seed in the form of seed accounts 51.87%. They recognize the impact of *R. raphanistrum* on crop stand, soil fertility and biodiversity but they were not aware of its allelopathic effects on the crops. Only 8.75% of the respondents aware about the allelochemical produced by wild radish that has a phytotoxic effect, which suppress the growth of the neighbor plants. This idea goes in line with the idea of (Singh 2009). Among the respondents, 84.4% of them were not aware of the wild radish impact causing the milk bitter.

Table 3. Extent of wild radish (*R. raphanistrum*) distribution, dispersal mechanisms, impacts and management methods employed

Study Parameters	Alternatives	Horro	A/Cho.	J/Rare	Amuru	Total	%
The extent of *R. raphanistrum* distribution status in your area	High	40	40	0	0	80	50
	Medium	0	0	0	20	20	12.5
	Low	0	0	18	12	30	18.75
	Absent	0	0	22	8	30	18.75
	Total	**40**	**40**	**40**	**40**	**160**	
Dispersal agents that you would expect for high spread of *R. raphanistrum*	Grain seeds	19	16	20	19	83	51.87
	Food aid	5	7	0	0	12	7.5
	Animals	3	6	6	4	19	11.87
	Floods	8	4	0	0	12	7.5
	Farm implements	2	5	10	7	34	21.25
	Vehicles	3	2	4	10		
	Total	**40**	**40**	**40**	**40**	**160**	
Land use type in which *R. raphanistrum* infestation is highest	Crop field	20	22	40	40	142	88.75
	Roadside	9	8	0	-	17	10.62
	Grazing land	11	10	0	0	21	13.12
	Total	40	40	40	40	160	
Have you heard or know *R. raphanistrum* has allelopathic effects on crops	Yes	8	6	0	0	14	8.75
	No	32	34	40	40	146	91.25
	Total	**40**	**40**	**40**	**40**	**160**	
Have you heard the impact of *R. raphanistrum* on milk when fed by dairy animals	Yes	11	14	0	0	25	15.6
	No	29	26	40	40	135	84.4
	Total	**40**	**40**	**40**	**40**	**160**	
Mechanisms of weed control by farmers							
• Cultural only		5	3	15	21	42	26.25
• Cultural & herbicide spray		33	31	21	19	106	66.25
• Herbicide spray only		2	6	4	0	12	7.5
	Total	**40**	**40**	**40**	**40**	**160**	

3.6. Level of R. raphanistrum infestation in Horro, Abayi Chomen, Amuru and Jima Rare Districts

The *R. raphanus* and other weed species distribution of the study area is indicated in (Table 4). This study showed that high infestation level of *R. raphanistrum* was observed in Horro district followed by Abayi Chomen. The means ± SD of *R. raphanistrum* per quadrate was 249.82 ± 34.67 at Horro and 164.87 ± 46.82 at Abayi Chomen district followed by Amuru district (70.95 ± 4.72) and Jima Rare (13.72 ± 14.16). The highest mean numbers of other weed species perquadrate were recorded at Amuru that is 516.57 ± 259.82. Least mean number of *R. raphanistrum* (13.72 ± 14.16) and other weed species (138.12 ± 432.48) per quadrat were recorded in Jima Rare district. The less number of *R. raphanistrum* and other weed species recorded at Jima Rare can be seen in to two different ways; less mean number of *R. raphanistrum* per quadrat clearly shows that *R. raphanistrum* is lately introduced weed species to the district and the less number of other weed species per quadrat shows that the farmers in the district experiences better weed management activities including other cultural practices. With the same expression, at kebele level the high mean number of *R. raphanistrum* was recorded in Doyo Bariso and Gudina Abuna of Horro district and Jare and Homi of Abayi Chomen districts (Table 5).

Table 4. Means and standard deviation (SD) of *R. raphanistrum* and other weed species by District

District	Wild Radish population per quadrate			Others weed species population per quadrate		
	Mean	SD	CI 95%	Mean	SD	CI 95%
Horro	249.82	34.67	208.7-296.8	264.7	58.03	161.3-332.3
Abayi Chomen	164.87	46.82	101.0-230.8	145.517	59.51	91.5-222.8
Jima Rare	13.72	14.16	0.0-40.5	138.12	32.48	97.3-180.8
Amuru	70.95	4.72	64.3-76.7	516.57	259.82	194.2-734.7

Table 5.Means and standard deviation (SD) of *R. raphanistrum* and other weed species by Administrative kebele

District	Kebele Name	Wild Radish			Others weed species		
		Mean	**SD**	**CI 95%**	**Mean**	**SD**	**CI 95%**
Horro	Doyo Bariso	266.2	39.95	221.0-296.8	304.38	24.22	289.3-332.3
	Gudina Abuna	233.43	24.55	208.7-257.8	255.03	56.79	161.3-265.0
Abayi Chomen	Homi	164.87	46.82	101.0-230.8	105.33	13.61	91.5-118.7
	Jare	192	39.05	152.7-230.8	185.7	61.85	114.3-222.8
Jima Rare	Sochosa Gamachisa	13.72	14.16	0.0-40.5	138.12	32.48	97.3-180.8
	Ibsa Ilamu	18.6	20.45	0.0-40.5	130.1	23.47	109.8-155.8
Amuru	Mekano	70.95	4.72	64.3-76.7	516.57	259.82	194.2-734.7
	Warra Bera	69.33	5.5	64.3-75.2	30.1.6	173.53	194.2-501.8
Total		**124.84**	**96.22**	**0-296.8**	**266.23**	**202.8**	**91.5-734.7**

The result of this study indicates that the issue is an urgent task to draw attention of responsible bodies and communities in general for managing and preventing further dissemination of this weed within the zone as well as in the country. The high infestation level and distribution of Wild radish, *R. raphanistrum* in HGWz of sampled areas are shown in Figure 2, 3, 4 and 5.

Figure 2.Wild radish (*R. raphanistrum*) and herbaceous vegetation stand in open field of Shambu Campus of Wollega University (Photo at Students Dormitory (a) Dairy Farm area (b, c & d), (Horo district, by Temesgen Fita)

Figure 3.Wild radish (*R. raphanistrum*) at flowering stage (a, b & c) and seed setting stage (d) in different fallow land replacing the native vegetation cover at Horro district, Doyo Bariso kebele [Photo by Temesgen Fita]

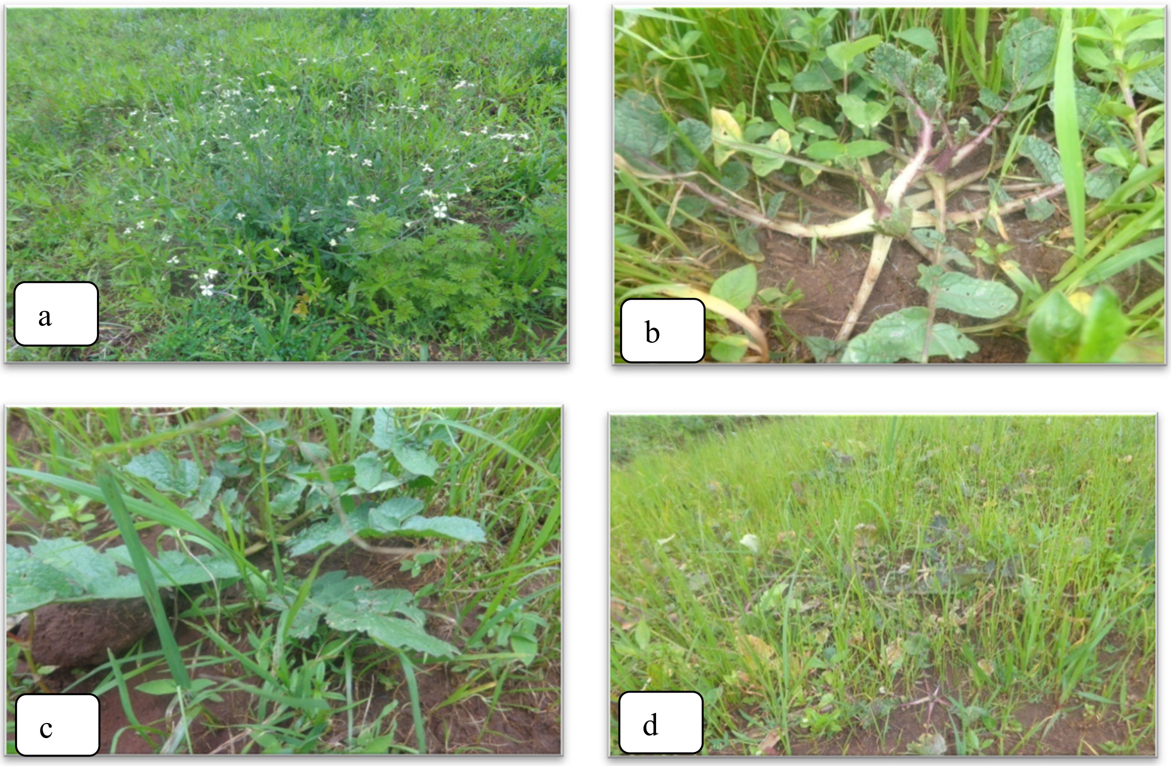

Figure 4.Wild radish (*R. raphanistrum*) vegetation covers in '*Noug*' (a) and '*teff*' (b, c & d) field at Amuru district, Makano kebele [Photo by Temesgen Fita]

Figure 5.Newly infested '*teff*'' field by Wild radish (*R. raphanistrum*) at Jima Rare district, Sochosa Gamachisa (a & b) and Ibsa Ilamu (c & d) kebeles' [Photo by Temesgen Fita]

3.7. Common weed species ranked first by respondents

The results of ranking common weed species and farmers' perception is depicted in Table 6. Among the respondents 89 (55.6%) of them ranked *R. raphanistrum* as a first dangerous weed because of its high spread and fast invasion in the field crops, along roadsides and along the margin of farmland. *Digitaria sp* ('serdo' or 'ye engicha sar') a common grassy weed in the study area ranked first by 25 (15.6%), *Bidense pachyloma* (Adey abeba) ranked as first by 11(6.9%) of the respondents, *Bidense pilosa* (Chegogit or ye seytan merfee) ranked as first by 10 (6.3%), *Guizotia sp* ranked as first by 9(5.6%) and *Cyperus sp* ranked as first by 16 (10%) of the respondents because it is well known distributed weeds in their surroundings with negative effects on native plants and crop yield.

Those respondents who did not know *R. raphanistrum* weed and ranked the other weed species as first were mainly from Administrative kebeles of Jima Rare and Amuru district which were lately infested by *R. raphanistrum*. Moreover, the farmers from Jima Rare and Amuru emphasized mainly on *Bidense pachyloma* and *Cyprus* sp, which is problematic weed in their field crop and home garden. The respondents who were unaware of *R. raphanistrum* (44.4% of the respondents) also explained that the *R. raphanistrum* weed has neither an impact nor negative effect on the growth and development of field crops and different plant species that have either economical or medicinal values (Table 6).

Table 6.Common weed species mentioned by respondents as first rank (N=160)

Weed species mentioned as 1st rank	Frequency of Respondents	%	Preference Rank
Digitaria sp.	25	15.6	2
Bidense pachyloma (Adey abeba)	11	6.9	4
Bidense pilosa (Chegogit)	10	6.3	5
Cyperus sp.	16	10.0	3
Guizotia sp (Mech)	9	5.6	6
R. raphanistrium	89	55.6	1
Total	160	100	

As to the respondents' of Horro and Abayi Chomen districts explanations, those weed species voluntary grown in open field which are impacted by *R. raphanistrum* are *Cyperus sp, Clover* (*Trifolium pretense*), Digitaria sp, *Cyanodon dactylon, Bidense sp, Chenopodium sp and* Rye grass. In the open field these weed species have various economical values as feed for animals. The respondents explained that the diversity and population stand of these weed plant species were impacted by *R. raphanistrum* have been decreasing from time to time in the previous infested area.

According to the farmers and agricultural experts" observation, the plant species in their surrounding that out-compete *R. raphanistrium* for long period of time are mainly *Bidense sp*, Cyprus sp, *Guizotia sp, Argemone Mexicana, Euphorbia pulcherima* and *Bidense pilosa* were some of the mentioned weed species. According to the majority of the respondents, the parasitic weed *Cuscuta campestris* (Yenug anbessa) is one of the most important weed considered as a 'silent killer' that reduces the annual production of *Noug*/Niger seed in the study area.

3.8. Vegetation data associated with wild radish and land use type

The vegetation data associated with *R. raphanistrum* with different invasion levels and the respective land-use type in 144 different sample sites are presented in Table 7. As it can be seen from the table that 18 (12.5%) samples sites were taken from each Administrative kebele of Horro, Abayi Chomen, Jima Rare and Amuru districts. The status of *R. raphanistrum* infestation were very high in Gudina Abuna & Doyo Bariso kebeles of Horro district and high in Homi & Jare kebeles of Abayi Chomen district. The infestation of *R. raphanistrum* in Gudina Abuna, Doyo Bariso, Homi, and Jare Administrative kebeles were observed in arable land, grazing land, roadsides and wasteland while in the rest of the four kebeles of Jima Rare and Amuru districts the *R. raphanistrium* infestation were only observed in arable land specially in the fields of cereal crops.

Table 7.Sample Sites of study area with wild radish infestation level and land use type

District	Ad/Kebele	No. of Sample sites	No. of Sample Quadrants	Level of infestation*	Land use type
Horo	D/Bariso	18	108	Very high	Field crops, road side, grazing land
	G/Abuna	18	108	Very high	Field crops, grazing land, road side
A/Cho	Homi	18	108	High	Field crops, road side, grazing land
	Jare	18	108	High	Field crops, grazing land, road side
J/Rare	S/Gam.	18	108	Low	Field crops
	I/Ilamu	18	108	Low	Field crops
Amuru	Makano	18	108	Moderate	Field crops
	W/Bera	18	108	Moderate	Field crops, grazing land
Total		**144**	**864**		

Key: Ad = Administrative Kebele; G/Abuna = Gudina Abuna; D/Bariso = Doyo Bariso; A/Com. = Abayi Chomen; J/Rare = Jima Rare; S/Gamachisa = Sochosa Gamachis; I/Ilamu = Ibsa Ilamu; W/Bera = Wara Bera
'*' Level of infestation based on *R. raphanistrium* infestation: Low (10-25%); Moderate (26-50%); High (51-75%); Very high (>75%) of the total percent of area coverage by *R. raphanistrium*

3.9. Cumulative and mean number of native and wild radish by vegetation type

Mean wild radish per quadrate is high in field pea field followed by wheat, which was 38.4 and 36.5 quadrate^{-1} (Table 8). The list mean per plot was in the fields of '*teff*' which accounts 30.6 quadrate^{-1}. '*Teff*' filed is prepared to make smooth which make favorable condition for '*teff*' seed for easy germination. This shallow, smooth and ramped seedbed suppresses the germination of wild radish found under the depth soil but weed seed found on top of the soil can germinate easily.

Table 8.Cumulative and mean number of native and wild radish by vegetation type sampled in filed crop plots in the study districts and Administrative kebeles

Crop type	Number of quadrate	Cumulative NoS species	Mean NoS quadrate^{-1}	Cumulative NoS of WR	Mean WR quadrate^{-1}
'*Teff*'	144	10637	73.8	4401	30.6
Wheat	144	11038	76.6	5251	36.5
Maize	144	13444	93.4	5012	34.8
Horse bean	144	13889	96.5	4920	34.2
Field pea	144	12724	88.4	5536	38.4
Noug	144	10486	72.8	4878	33.9
Total	864	72218	83.6	29998	34.7

Key: NoS = Number of samples, WR = Wild Radish

3.10. Weed species composition diversity and evenness

The herbaceous vegetation data associated with *R. raphanistrium* had shown 53 plant species recorded and classified under 22 families. From the recorded plant families, *Poaceae* (*Gramineae*) accounts the largest (27.8%), *Legumineae* (18%), *Solanaceae* (17.3%), *Compositae* (*Asteraceae*) (15.6%), *Fabaceae* (*Amaranthaceae* (12.9%), and *Euphorbiaceae* accounts 8.4% each holding the third place among the plant species recorded in the study area.

Among the common few weed species recorded during the survey were: *R. raphanistrum, Bidense pachyloma* (Adey abeba), *Bidense pilosa* (Chegogit seytan merfee), *Andropogon abyssinicus* (Belem), *Datura stramonium* or Jimsonweed (Atsefaris), *Digitaria sp* (*Poaceae*), *Cyperus rotundus* (ye ahiya sedrdo), *Cyperus esculantus* (Ingicha), *Plantego lanceolata* (Gourteb), ***Parthenium hysterophorus,*** *Bromus pectinatus, Cuscuta campestris* (Yenug anbessa), *Orobanche ramosa* (Yemidir kiting or yejib iras), *Galinsoga parviflora* (deha nekel, Yemedir berbere), *Guizotia sp* (mech), *Tagetus minota* (Gema hashish, ye ahiya shito), *Launaea cornuta* (ye seytan gomen), *Xanthium sp, Amaranthus sp., Bromus rectorum, Chenopodium album, Chenopodium carinatum, Rumex acetosa* (*Polygonaceae*), *Solanum nigrum* (Solanaceae), *Thistle sp* (composite), *Trifolium* sp [White clover (*Trifolium repens* L.), Red clover (*Trifolium Pratense* L.), (*Fabaceae*)], *Ipomoea sp* (*Convolvulaceae*), *Galium sp* (*Rubiaceae*), Lolium sp (rye grass), *Panicum sp* (*Poaceae*), and *Acanthaceae* (Acanthaceae) were among common weed species, Curly dock (*Rumex crispus* L.), Common Mallow (*Malva neglecta)*, Day flower (*Commelina communis*), Lambs quarter (*Chenopodium album*), Carolina horsenettle (*Solanum carolinense*) *(Solanaceae)*, Bull Thistle (*Cirsium vulgare*), Canada Thistile or Creeping thistile (*Cirsium arvense*), Annual Bluegrass (*Poa annua*), Bermuda grass or Wire grass (*Cynodon dactylon*) and Common Chickweed (*Stellaria media*) few of weed species. The weed species recorded during the study were collected, pressed, and identified by using "Hand book on Weed Identification" Naidu (2012).

The biodiversity impact of *R. raphanistrium* weed on highly infested areas was more visible than the moderate and low infested areas. The sampled sites in Horro district starting from Doyo Bariso to Gudinna Abuna (Sakala and Dimbe area) have lower diversity index (H) (highly infested area) as compared to other sites where the calculated Shannon Diversity Index is high (where invasion was low) (Table 9). Horro and Abayi Chomen showed the lowest Shannon Diversity Index value of 1.78 and 2.12 respectively due to the fact that, their species diversity was highly affected by the high infestation of *R. raphanistrium*. Comparatively, the Sochosa Gamachisa, Ibsa Ilamu, Makano and Wara Bera administrative kebeles have a diversity Index of greater than 4.0 showing low *R. raphanistrium* infestation in the area and the its impact on species diversity is low. This is because of the early infestation of the two sample districts of the study area.

Similarly, the evenness index was found to be higher in un infested areas which indicated that the species are evenly distributed. This is true in this present study sites such as Sochosa Gamachisa, Ibsa Ilamu, Makano and Wara Bera administrative kebeles, where the evenness index were above 4.12 which shows the sampled area were less infested by *R. raphanistrium*. In contrast, the fact that it was lesser in the *R. raphanistrium* infestation, the area indicated patchiness in distribution, which shows a few species dominate the area.

Table 9.Shanon Diversity index (H), Species richness (S) and Evenness (E) in the study area

District	Study Kebeles'	H	S	E
Horo	Doyo Bariso	1.78	32	0.5
	Gudina Abuna	2.12	34	0.4
Abayi Chomen	Homi	2.51	31	0.8
	Jare	2.18	35	0.9
Jima Rare	Sochosa Gamachisa	5.84	40	1.2
	Ibsa ilamu	5.28	39	1.1
Amuru	Makano	4.22	40	1.6
	Wara Bera	4.12	38	1.4

This study showed that in the study areas of *R. raphanistrium* infested sites the numbers of desirable weed plant species were highly declined. Such a reduction could be attributed to the increasing abundance of the *R. raphanistrium* in the sites. The result of this study goes in line with the study of Kohli *et al*. (2004) and Sakai *et al.* (2001) where invasive plants are known to exert significant impact on the natural communities as they cause their displacement and hence bear imbalance in the natural and agricultural ecosystem. This imbalance causes the formation of large monoculture of invasive plants in the alien environment. The weed affects not only the species diversity of the native areas, but also their ecological integrity. Moreover, environmental degradation and disturbance favors the invader species such as *R. raphanistrium* weed. Under such circumstances, the weeds easily establish themselves in the sites and start interfering with other native species by suppressing their potential growth and biomass production. *R. raphanistrium* was known to suppress the associated species through the release of allelochemicals from decomposing biomass and root exudates into the soil environment (Norsworthy 2003; Malik 2009).

There is a high negative correlation between mean *R. raphanistrium* density and Shannon diversity index with $R^2 = 0.642$, $p<0.001$. The equation for the regression line is y = 38.53- 1.959 (Figure 6). High negative correlation means that as the mean *R. raphanistrium* density increases, the Shannon Diversity Index decreases. This in turn shows the *R. raphanistrium* effect on the biodiversity of plants.

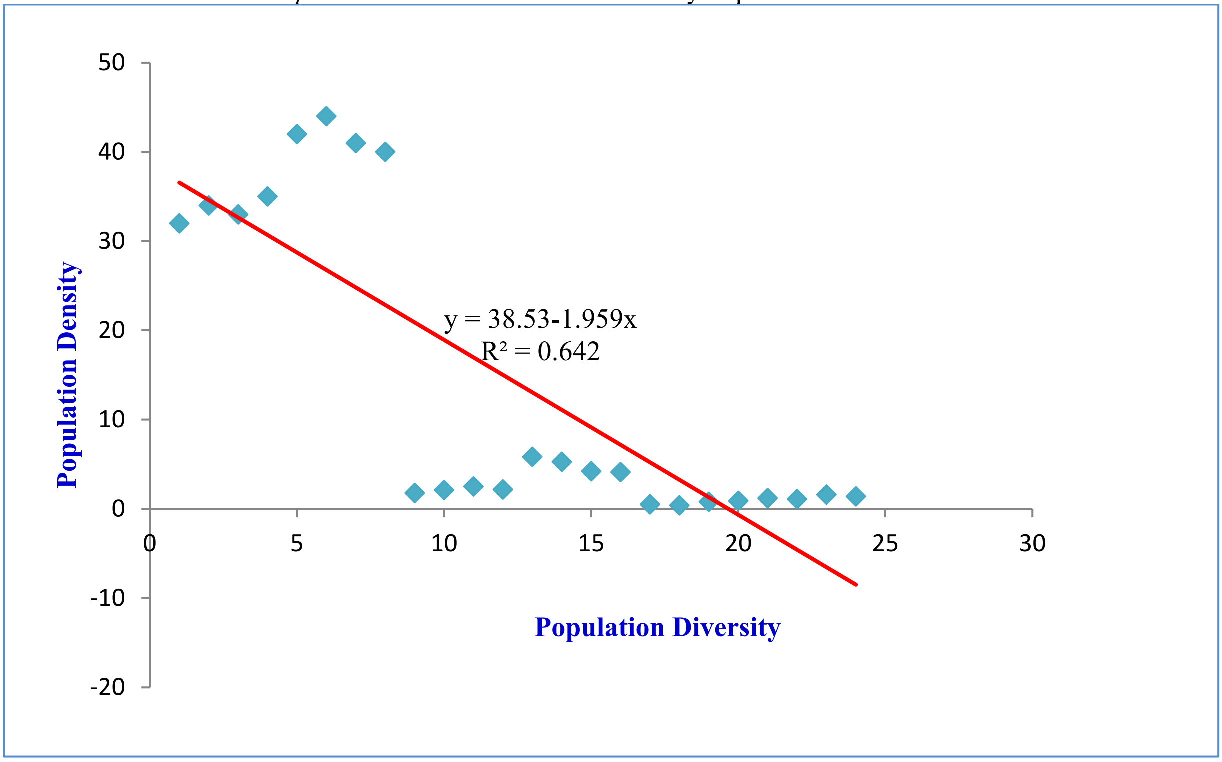

Figure 6.Correlation between Raphanus density and Shannon Diversity index

3.11. Jaccards Similarity Coefficients (JSC) of Herbaceous Vegetation

The Jaccards Similarity Coefficients of standing herbaceous vegetation associated with *R. raphanistrium* at 8 sampled Administrative kebeles' of 144 sites and 864 quadrates is depicted in Table 10. This coefficient of similarity has values from '0 to 1', where '1' reveals complete similarity and '0' complete dissimilarity. Thus, the standing herbaceous vegetation from the sampled sites of the Doyo Bariso and Gudina Abuna administrative kebeles showed higher Jaccards Similarity coefficient (greater or equal to 0.84), where there was high *R. raphanistrium* infestation level. This was due to the complete dominance of *R. raphanistrium* weed over other herbaceous plant species of the study area.

The high similarity value between *R. raphanistrium* invaded areas of Doyo Bariso and Gudina Abuna administrative kebeles indicated that there is no radical change on species composition within the area. In contrast, other kebeles from Jima Rare (Sochosa Gamachisa and Ibsa Ilamu kebeles') and Amuru (Makano and Wara Bera kebeles') districts showed relatively lower similarity coefficient than administrative kebeles from Doyo Bariso and Gudina Abuna revealing low impact of the wild radish weed in the area.

Table 10.The JSC of the Standing Herbaceous Vegetation among eight administrative kebeles'

	Do/Ba	Gu/Ab	Homi	Jare	So/Gam	Ib/ila	Mak	Wa/Be
Do/Ba								
Gu/Ab	0.84							
Homi	0.83	0.85						
Jare	0.78	0.80	0.85					
So/Gam	0.86	0.82	0.74	0.78				
Ib/Ila	0.83	0.79	0.86	0.76	0.22			
Mak	0.91	0.84	0.76	0.85	0.18	0.21		
Wa/Be	0.82	0.76	0.81	0.83	0.21	0.23	0.24	

N.B: Do/Ba = Doyo Bariso, Gu/Ab = Gudina Abuna, So/Gam = Sochosa Gamachisa, Ib/IIa = Ibsa Ilamu, Mak = Makano, Wa/Be = Wara bera

3.12. Comparison and correlation of mean R. raphanistrium density

The study of *R. raphanistrium* mean density and species richness in eight PAs, is shown in Table 10. Jare has the first highest mean *R. raphanistrium* density, which accounts 62.7 m^{-2} but with relatively low species richness. Gudina Abuna and Doyo Bariso accounts the second highest mean *R. raphanistrium* density, which is 60.9 and 60.7 m-2 with the species richness value of 34 and Homi, accounts the fourth highest with its mean 54.7 m^{-2} *R. raphanistrium* density comprising species richness of 35. In general, the result from the table shows that there was a trend of decrease of species richness as the mean *R. raphanistrium* density is increasing in the study sites. This is particularly true in Horro (Doyo Bariso and Gudina Abuna kebeles) and Abayi Choman district (Homi and Jare kebeles), and in areas where the distribution of *R. raphanistrium* weed is highest, respectively, as compared to other study sites. In contrast, species richness increases as mean *R. raphanistrium* density decreases as in the case of sample sites such as Wara Bera, Makano, Ibsa Ilamu and Sochosa Gamachisa kebeles'. This definitely shows the impact of *R. raphanistrium* weed on species diversity and hence in species richness of the study area.

Table 11.Mean comparison of *R. raphanistrium* density and species richness'

District	Sample Kebeles'	Mean Wild radish Density	Species richness
Horo	Doyo Bariso	60.71	32
	Gudina Abuna	60.95	34
Abayi Chomen	Homi	54.69	33
	Jare	62.67	35
Jima Rare	Sochosa Gamachisa	16.63	42
	Ibsa Ilamu	10.61	44
Amuru	Makano	30.73	41
	Wara Bera	31.81	40

Table 12.Mean Comparison and correlation of mean *R. raphanistrium* density quadrates^{-1}

District	Kebele	Mean number		Species richness (S)
		Wild radish	Other Weeds	
Horo	Doyo Bariso	60.71	85.72	32
	Gudina Abuna	60.95	76.11	34
	Mean	60.83	80.92	33
Abay Chomen	Homi	54.69	60.33	31
	Jare	62.67	77.34	35
	Mean	58.68	68.84	33
Jima Rare	Sochosa Gamachisa	6.63	62.67	40
	Ibsa Ilamu	1.61	66.34	39
	Mean	4.12	64.51	39.5
Amuru	Makano	6.73	144.5	40
	Wara Bera	11.81	95.67	38
	Mean	9.27	120.08	39

3.13. Mean of Wild Radish height, branches and flower head mean number per plant

The mean of *R. raphanistrium* height, number of branches and number of flower heads counted in three different times (at the beginning of June, July, September and October) in eight Administrative kebeles'under 144 sample sites are shown in Table 13. From the table, the highest mean height (0.96m) of Raphanus was recorded in Jare kebele. The specific localities where this height recorded were along the way to Fincha town. The average number of branches counted in the same localities was 44 followed by Doyo Bariso where number of branches per plant was 42 with an average height of 0.88m. Generally, the findings of this research shows a decreasing trend of mean height, number of branches, and flower head plant^{-1} from Jare to Mekano kebele (that is, from sample sites along the way from Abayi Chomen, Horo, Jima Rare to Amuru district). The mean number of wild radish flower head counted per plant showed a considerable increase from June, July to October particularly in highly infested areas, especially Shambu town surrounding W.U. Shambu campus, Doyo Bariso and Gudina Abuna sites of Horo district and Homi and Jare site of Abay Chomen district. The increased number of flower head/plant counted in September may be because of optimum rain that the area has got during the time of data collection.

From this study, it was found that the average number of flower heads plant^{-1} counted in September and October was greater than that of the remaining two rounds for all the sites in the Doyo Bariso and Gudina Abuna sites, where the level of infestation was higher. In comparison, Jare kebele has the highest average number of flower heads counted plant^{-1} was 1234 in two rounds followed by Doyo Bariso, which was counted 1216 flower heads plant^{-1} (Table 13). The average numbers of flower heads counted for the sample sites of Ibsa Ilamu and

Sochosa Gamachisa of Jima Rare district and Makano of Amuru districts are very low as its level of infestation was lower due to its late emergence of this weed into these localities.

Table 13.Comparisons of mean height stem branches and flowers of *R. raphanistrium* density and species Richness'

District	Sample Kebeles'	Mean height (cm)	Number of basal branches plant^{-1}	Flower heads plants^{-1}
Horo	Doyo Bariso	88	42	1216
	Gudina Abuna	86	34	1142
Abay Chomen	Jare	96	44	1234
	Homi	92	38	1102
Jima Rare	Sochosa Gamachisa	60	22	867
	Ibsa Ilamu	54	16	783
Amuru	Makano	52	18	985
	Wara Bera	64	28	1124
	Average	**74**	**23.25**	**1056.6**

3.14. The competitive ability of plant species

Even though the experiment on the competitive ability of plants was not done in this present study, it is feasible to list down plant species that frequently occurred in the sampled sites of infested areas tolerating the ill effects of *R. raphanistrium*. Thus, the plant species that can tolerate the effect of *R. raphanistrium* weed have the highest relative frequency indicating its frequent occurrence in both highly infested and low infested areas (Table 14). Even though their abundance varies, the occurrence of *R. raphanistrium* weed was 456 (79.2%) out of 576 sampled quadrates. Accordingly, Cyprus sp was the second frequently occurred plant species with the relative frequency of 70.8% in the mentioned study area and thirdly Digitaria sp which occurred in 70.3% out of sampled sites.

Table 14.Relative frequency of twelve plant species in the study area

Weed species	Frequency	Relative Frequency
Digitarium sp	405	70.3
Bidense pachyloma (Adey abeba)	372	64.6
Bidense pilosa (Chegogit)	342	59.4
Cyprus sp.	408	70.8
Cynondon dactylon	402	69.8
Guizotia scabra (Mech)	366	63.5
Euphobia hirta	267	46.3
Plantago lanceolata (Gurteb)	216	37.5
Eragrostis sp.	348	60.4
Yenug anbessa (*Cuscuta campestris*)	189	32.8
Datura stramonium (As'teffaris)	276	47.9
R. raphanistrium	456	79.2

This is so because *R. raphanistrium*, *Ageratum conyzoides* and also *Euphorbia sp.* are tropical in origin and they possess similar growth strategies. They grow fast, deep rooted that help the plant to extract minerals and water in the sub soil and they have greater reproductive potential, competitive ability, and allelopathy that make them successful invaders of non native habitat (Grice, 2006). Due to its high growth rate, *R. raphanistrium* becomes competitive and develops the ability to exclude the growth of other species (Table 15).

Table 15. Frequency, density, and abundance rank of *R. raphanistrum* from weed surveys of selected 4 field crops in 8 administrative kebeles' of four districts of HGWz

District	Kebeles	Crop	Year	Density No. m^2	Frequency (%)	Relative abundance rank
Horo	Doyo Bariso	Maize	2016^*	38.33	68	2
		Teff	2016^+	40.06	54	7
		Wheat	2016^+	44.28	63	4
		Noug	2016^+	33.9	65	3
Horo	Gudina Abuna	Maize	2016^*	35.28	71	1
		Teff	2016^+	26.83	49	9
		Wheat	2016^+	35.4	59	6
		Noug	2016^+	32.1	61	5
A/Chomen	Homi	Maize	2016^*	29.2	52	8
		Teff	2016^+	29.4	43	11
		Wheat	2016^+	20.5	38	13
		Noug	2016^+	14.8	33	15
A/Chomen	Jare	Maize	2016^*	41.6	46	10
		Teff	2016^+	16.3	37	14
		Wheat	2016^+	24.7	41	12
		Noug	2016^+	22.4	29	16
Jima Rare	S/Gamachisa	Maize	2016^*	0.0	11	22
		Teff	2016^+	4.1	6	27
		Wheat	2016^+	0.0	3	30
		Noug	2016^+	0.0	7	26
Jima Rare	Ibsa Ilamu	Maize	2016^*	3.06	14	21
		Teff	2016^+	2.94	5	28
		Wheat	2016^+	7.94	4	29
		Noug	2016^+	2.5	2	31
Amuru	Makano	Maize	2016^*	10.89	14	20
		Teff	2016^+	11.33	8	25
		Wheat	2016^+	22.56	11	21
		Noug	2016^+	6.06	5	28
Amuru	Wara Bera	Maize	2016^*	10.9	21	17
		Teff	2016^+	13.3	13	22
		Wheat	2016^+	23.2	18	18
		Noug	2016^+	7.22	15	19
	Mean			**19.09**	**60.37**	

N.B. '*'Weed sample collection and population density counting was done in 2016 in the months of July, August, September, October, November and December and '+' September, October, November and December.

3.15. Severity status of R. raphanistrum in common field crops host plants

In all the study area cereals, legumes and horticultural crops were observed as major host plants for *R. raphanistrum* (Table 16). It occurs in most of field crops and horticultural crops within geographical range of the study sites. This study is in line with the study of Holm *et al.* (1997) which stated that *R. raphanistrum* is a major weed of cereals, especially wheat, particularly winter-sown wheat. It is also common in a number of field crops like maize, *tef*, barley, , legumes crops, horticultural crops, pastures and fodder crops. It is likely to occur in any crop within its geographical range.

Table 16.Host Plants (field crops and horticulture crop) affected by *R. raphanistrum*

Crop Name	Family	Context	Severity
Maize (*Zea maize*)	*Poaceae*	Main	High
'*Teff*' (*Eragrostis 'teff'*)	*Poaceae*	Main	Very high
Wheat (*Triticum aestivum*)	*Poaceae*	Main	Very high
Barley (*Hordeum vulgare*)	*Poaceae*	Main	Very high
Field Pea (*Pisum sativam*)	*Fabaceae*	Main	High
Horse bean (broad bean)	*Fabaceae*	Main	High
Noug (*Guizotia abyssinica*)	*Asteraceae*	Main	High
Flax/linseed(*Linum usitatissmum*)	*Linaceae*	Main	Very high
Rape (*Brassica napus*)	*Brassicaceae*	Main	High
Potato (*Solanum tuberosum*)	*Solanaceae*	Main	Moderate

3.16. Wild Radish Management Practices exercised by growers' indigenous knowledge

Not only for *R. raphanistrum,* for all weed management 87% of the respondents responds practicing of winter soil cultivation starting from the month of February until seed sowing. The rest 9% practice mechanical destruction and 4% practice hand weeding. After crop emergence growers uses different measures of weed management including *R. raphanistrum*. Among them chemical control, hand weeding and slashing (mechanical destruction) is the commonly practiced methods. Among the respondents 47% of them responded the application of herbicide (2, 4-D), 42% responded hand weeding and 11% responded slashing.

As long as the management is concerned, hundred percent of the respondents who knew the weed before this study only mentioned hand hoeing/hand pulling/uprooting and burning of wild radish weed in its early period before it sets flowers.

3.17. Associations of Biological Control Agents (Pathogen and Insect) with Raphanus raphanistrum

During field surveys un identified potentially pathogenic fungi was found from naturally infected *R. raphanistrum* in field conditions from the seedling stage up to plant maturity in the districts Horo (Doyo Bariso kebele) and Abayi Chomen (Homi kebele) (Figure 7). It was the first pathogen to produce disease symptoms on *R. raphanistrum*, occurred in winter. During field survey, it was not observed on neighboring edible *brassicaceae* plants, which in the future invites for in-depth study. White pustules of sporangia of this *oomycete* were generally located on the leaves and stems and occasionally on the inflorescences and pods of *R. raphanistrum*. *Erysiphe cruciferarum* ***and other pathogenic fungi*** caused severe infections on the vegetative and reproductive parts of wild radish plants (Naceur *et al*., 2009; Ravi *et al*., 2014). Symptoms first appeared as circular to irregular white patches on both sides of the leaves, and on stems and pods, often thinly covering the whole surface.

Figure 7.Wild radish naturally infected by pathogenic fungi (downy mildew) at Horo district (Doyo Bariso) and Abayi Chomen (Achane), showing developmental stage,[Photo by Temesgen Fita]

3.18. Insects as Biological Control Agents

Aphid species (white aphids) and ladybird beetles (green ladybird beetles) make associations with *R. raphanistrum*. Wild radish plant fed by this aphid was stunted in growth and physiological stand and leaf development was seen reduced. Its secretion of honeydew causes white sooty mildew to grow on the plant, thus further reducing the photosynthetic area of the host plant. Even though wild radish is affected by aphid and powdery mildew the host spasticity of these two agents needs further research whether they are host specific or not.

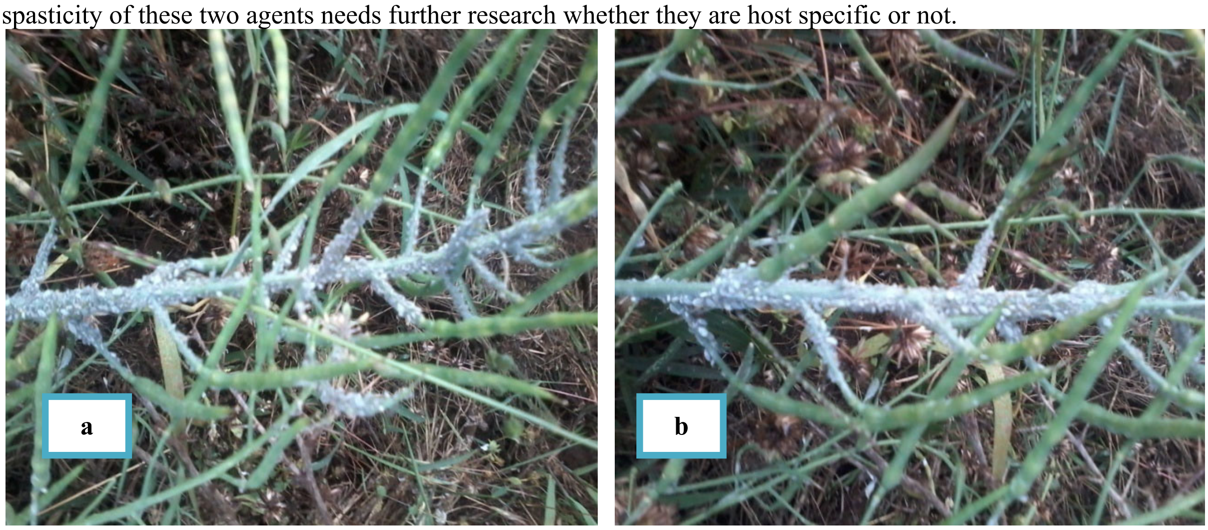

Figure 8.Wild radish naturally infected by Aphids sp. (White Aphids) (a & b)

Figure 9.Wild radish naturally infected by Adult Coccinellidae sp. (Green Ladybird Beteel)

4. Discussion

The study showed that heavy and widespread infestation of *R. raphanistrum,* mostly on farmlands, field crop borders, roadsides, grazing and fallow lands of Horo and Abayi Chomen districts of Horo Guguru Wollega zone (HGWz). *R. raphanistrum* grows and develops very well in fallow lands of farm fields. During field travel of the survey *R. raphanistrum* has been observed in the field crops of Guduru, Jima Geneti and Jardega Jarte districts of HGWz, along the roadsides and near dwelling sites. The *R. raphanistrum* infestation was also observed on some fields and road sides of west Showa zone of Chelia District in the farm fields of wheat, barley and *''teff''* and around Gedo town. This report is in agreement with the finding of Holm *et al*. (1991) who reported the initial occurrence of *R. raphanistrum* in Ethiopia at 'Say Ager' area. The result of this study indicated that the exchange of grain seeds within administrative kebeles' and districts, and the foothold weed seeds by animals' and human activities aided the weed dispersal extensively into adjacent agricultural lands and neighbor districts.

From the result of the study it was found that 89(55.6%) of the interviewed farmers rank *R. raphanistrum* as the first and most serious weed in rangelands and croplands. Similarly, from the respondents of this present study *R. raphanistrum* has a great impact on crop plant species as mentioned previously in the result. Very little or sometimes no other vegetation were seen in *R. raphanistrum* dominated areas of Doyo bariso, Gudina and Abuna of Horo district, and Achane and Jare of Abayi Chomen district. Warwick and Francis (2005) who reported that, because of its efficient biological activity and adaptability to varying soils and microenvironments, evidence this, *R. raphanistrum* weed has a tendency to replace the dominant flora in wide range of habitats cutting across zonal boundaries and agro-climatic conditions. The field observation during our survey shows that wherever it invades, it forms a territory of its own by replacing the indigenous natural flora including pasture grasses. The study conducted by Norsworthy (2003), Malik (2009) and Singh (209) indicated that the *R. raphanistrum* allelopathic properties through the release of allelochemicals, which cause inhibition of germination and suppression of natural vegetation and associated plant species including the cereal crops and medicinal herbs, pose a strong threat to biodiversity. Respondents of the study area explained their idea as they did not recognize the impact posed by wild radish but heard about the impact of the *R. raphanistrum* on crop and grazing land, seed grain market, milk quality and biodiversity.

This present study revealed that there was a sharp decline of herbaceous plant diversity index as the density of *R. raphanistrum* increased. This reality can be observed from 'Figure 2 and 3', which shows the existing field reality, how the local herbaceous species are being replaced by wild radish, *R. raphanistrum*. The result of this study is similar with Burns *et al*. (2013) and Lesley *et al*. (2014) findings where the Shannon index shows greater plant diversity in un infested area, whereas the index was reduced by 36 to 51% in the *R. raphanistrum* infested areas. Therefore, the higher value of the diversity index indicates the variation in the type of species and the heterogeneity in the community, whereas the lesser value points indicates the homogeneity in the community. In areas of high *R. raphanistrum* infestation, there was also a high mean *R. raphanistrum* density per m^2 as described in Figure 5. This is probably due to high viability of the *R. raphanistrum* seed banks in soil. Thus *R. raphanistrum* density per m^2 is often increasing in every generation, unless intervention is taken to control its distribution and invading un infested areas. This is because *R. raphanistrum* is capable of emerging and producing seeds during most of the year (Singh 2009).

This present study identified that the mean number of native weed plants and *R. raphanistrum* by vegetation type in the sampled filed crop quadrate^{-1} were 41.3 and 26.3, respectively. The minimum and maximum-recorded mean number of native weed plants and *R. raphanistrum* was 20.9 - 61.8 and 19.2 - 53.7, respectively. This finding shows that how the newly emerging weed plant, *R. raphanistrum* hardly replacing the native weed species. This study goes in line with the finding reported by Cheam & Code (1998).

The number of flower head capitula^{-1} for this present study is much higher where a single plant producing an average of 1056.6 flower heads. This might be because of the fact that the season for data collection was more suitable for *R. raphanistrum* growth and development. In this present study, germination usually occurs after the 1st rain of March, but continuous new flushes occur throughout the year after rain. Roberts and Boddrell (1983) reported that in Australia germination usually occurs after autumn rains, but "flushes" of germination occur throughout the year after rain. In the UK the peak period of germination is in March and April, but seedlings continue to appear until late autumn. *R. raphanistrum* flowering occurs from late July (4-12 weeks after emergence) and can continue for 12-42 weeks (Lee & Snow 1998; Malik, 2009). Moreover, the above data showed certain similarity with the study done in South Carolina by (Singh, 2009). He described that the inflorescence bearing flowers started appearing in late July or early August. The flowering stage in some plants lasted until November and then seed setting started. In the present study, the rainy season (July, August and September), some new seedlings emerged and they flowered in September and lasts up to November. In October, the seed setting was observed in most of the plants. The seeds fully ripened in the month of November and December or it completed its life cycle by that time.

The plant species that were identified from this present study which have *R. raphanistrum* competitive ability for long period are mainly *Bidense sp*, Cyprus sp*, Guizotia sp, Argemone Mexicana, Euphorbia pulcherima* and *Bidense pilosa* were some of the mentioned weed species. Due to its high growth rate and its adaptability, *R. raphanistrum* becomes competitive species and it develops the ability to colonize and exclude the growth of other species affecting the biodiversity of the study area. *R. raphanistrium* endanger the native biodiversity by choking and deliberate takeover of the native plants in Horo and Abayi Chomen districts, which goes in line with the finding of Holm *et al.* (1997), Warwick and Francis (2005), Wilson *et al*. (2009) and Barnaud *et al*. (2013). Majority of the respondents were not aware of about the allelopathic chemical produced by *R. raphanistrum* that has a phytotoxic effect on neighboring plants, which suppress the growth of the neighbor plants. The inhibitory allelopathic effect of *R. raphanistrum* associated with the production of glucosinolates (GSLs) on the germination and seedling development of plants was previously studied by (Norsworthy 2003; Singh 2009).

Moreover, during data collection un identified naturally occurring fungi pathogenic found attacking both the vegetative and the reproductive parts of the wild radish, *R. raphanistrum*. This finding goes in line with the result stated by Ravi, *et al*. (2014) who reported that in Ethiopia at Horo Guduru Wollega zone of Oromia Regional state *R. raphanistrum* was found infected by naturally occurring fungi pathogenic *Erysiphe cruciferarum,* which was for the first report in Ethiopia. The same study by Naceur *et al*. (2009) mentioned that in Tunisia fungus isolation from the foliar tissues exhibiting disease symptoms showed that *R. raphanistrum* was infected with the fungi *Erysiphe cruciferarum, Albugo candida, Alternaria* spp. including *A. brassicicola,* and *A. raphani, Stemphylium herbarum, Peronospora parasitica* and *Phoma lingam*. *Ascochyta* spp., *Cercospora armoraciae, Cladosporium cladosporioides* and *Colletotrichum higginsianum* are here reported from *R. raphanistrum* for the first time. In addition to this un identified green Coleoptera was found attacking *R. raphanistrum* in the study areas of Horo district that warrant assessment for use in classical biological control. Foliar pathogenic fungi and insect biological control have a potential in the integrated weed management of *R. raphanistrum*, these two role merits further investigations Naceur *et al*. (2009).

For restricting the entrance of *R. raphanistrum* seed into a non-infested area, avoiding buying grain seeds from infested area and sowing clean seeds, avoiding exchange of hay and crop straw from *R. raphanistrum* infested areas and quarantining stock that have recently been in infested areas are vital for reducing *R. raphanistrum* spread. In *R. raphanistrum* infested areas to minimize the population of the latter emerging weed seedlings, shallow cultivation following early coming rains will increase seedling emergence. Cultural control practices including uprooting of the weed before flowering and seed setting must normally be combined with chemical treatments to ensure effective control of this weed. *R. raphanistrum* is capable of emerging and producing seeds during most of the year, and season-long control measures should be adopted to prevent seed production and replenishment of the *R. raphanistrum* soil seed bank.

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5. Conclusions

In conclusion, the prevalence and rapid colonization potential of *R. raphanistrum* over long distances facilitate its rapid spread within the zone and neighbor zone. An important consideration would be thus; since this species is already widely distributed throughout Horo Guduru Wollega zone, locally occurring in high densities our understanding of the colonization dynamics of *R. raphanistrum* invasions can have a direct impact on crop yield and biodiversity of the study area as well as impact on the region and the nation. It is also a prolific seed producer and can cause yield losses if not controlled in a timely manner. Furthermore, our study demonstrated the influence of *R. raphanistrum* colonization and pathway of this weed invasion. Indeed, until now the biological and anthropogenic invasions have received far less attention compared to ecological processes. Large numbers of the respondents were not aware of the nature and impacts of this invasive weed on the biodiversity and microenvironment. Our knowledge on *R. raphanistrum* invasion nature can greatly benefited from the recent study in developing and advising management strategies of this invasive weed for the communities and concerned government institutions based on geographical and environmental features at both the population and individual level.

Given the opportunity to address problems of invasive alien plant species (IAPS), the priority must be to create public awareness and action through disseminating the information on risky species. As concern and awareness of IAPS problems, including *R. raphanistrum,* grows in the study area, the initial action often taken should be containing *R. raphanistrum* to prevent its dissemination in to un infested area. The survey should include checking the presence and severity of other invasive weed species problems. In infested areas, an accurate assessment of the target weed plant (*R. raphanistrum*) infestation will help to contain and preserve the neighboring un infested land and enhances the success of future large-scale control programs. Preventing encroachment into the land that is not infested, detecting, and eradicating new weed introductions, containing large-scale infestations using an integrated approach will help in managing this newly emerging invasive weed.

Weed control should focus only not on croplands, but focus on fallow lands, roadsides, rangelands and waste sites with an understory of residual weed plants. Suppressed weeds have the greatest chance of reestablishing dominance on these sites. These areas must be spot treated each year to ensure control and minimize reinvasion of the emerging invasive weed species. In these cases, some of the weed management unit will require control measures that are repeatedly applied until the weed seed bank and root reserves are exhausted. Control methods used must be based on the biology of the weed. When doing so, the next control efforts should focus on the sites adjacent to those initially treated to minimize reintroduction of the weeds.

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REFERANCES

Barnaud, A.; Kalwij, J. M.; McGeoch, M. A.; Jansen van Vuuren, B. (2013), Patterns of weed invasion: evidence from the spatial genetic structure of *Raphanus raphanistrum.* Biological Invasions, 15:2455-2465

Belay Beyene, Demissu Hundie1 and Geleta Gobena. 2015, Assessment on Dairy Production System and its Constraints in Horoguduru Wollega Zone, Western Ethiopia. *Sci. Technol. Arts Res. J.,* 4(2): 215-221 DOI: http://dx.doi.org/10.4314/star.v4i2.28

Blackshaw, R.E. (2001), 'Influence of wild radish on yield and quality of canola', *Weed Science*, 50 (3): 344-349.

Burns, J. H., Pardini, E. A., Schutzenhofer, M. R., Chung, Y. A., Seidler, K. J. and Knight, T. (2013), Greater sexual reproduction contributes to differences in demography of invasive plants and their noninvasive relatives. *Ecology*; 94: 995-1004

Cheam, A. H., and Code, G. R. (1995). The biology of Australian weeds. Plant Prot. Quat. 10:3-13.

Cheam, A.H. (1986), Seed production and seed dormancy in wild radish (*Raphanus raphanistrum* L.) some possibilities for improving control: Weed Res. **26**: 405–413.

Cheam, AH and Code, GR. (1998), *The Biology of Australian Weeds*, vol. 2, ed. F.D. Panetta, R.H. Groves and R.C.H. Shepherd, R.G. and F.J. Richardson, Melbourne.

Chellamuthu A, Nadanassababady P, Rammohan J. (2005), Present status of *Parthenium hysterophorus* L. in the coastal regions of Pondicherry and Karaikal. In: Proceeding of the Second International Conference on Parthenium Management 5-7 December2005. University of Agricultural Science Bangalore, India, pp. 44-47.

CSA (Central Statistical Agency) of Ethiopia (2016), Agricultural Sample; The Federal Democratic Republic of Ethiopia Central Statistical Agency (CSA) Report on Area and Production of major crops; Private Peasant

Holdings, *Meher Season*, 1: 1-58.

CSA (Central Statistical Agency) of Ethiopia. (2007), Population and Housing Censes of Ethiopia, Ethiopia Population Census Commission.p385

Dechasa Lemesa. (2003), Field Assessment Report. Surplus Producing Eastern highlands of East Wollega zone Badly hit by current crises, United Nations Office for the Coordination of Humaniterian Affairs (UN OCHA), Ethiopia, pp.10.

Dikova B, (1989), Wild-growing hosts of the cucumber mosaic virus. Rasteniev'dni Nauki, 26(7):57-64

DIR 139. (2016). Risk Assessment and Risk Management. Plan for Commercial release of canola genetically modified for herbicide tolerance Applicant: Pioneer Hi-Bred Australia Pty Ltd; Australian Government Office of the Gene Technology Regulator,pp60.

Garcia EF. (1988), Spring and summer hosts for Pieris rapae in southern Spain with special attention to Capparis spinosa. Entomologia Experimentalis et Applicata, 48(2):173-178

Goshu, Firdisa Birru (2016), Determinants of Smallholder Farmers' Participation Decision in Teff Production: Evidence from Horo and Jima Geneti Woreda, Ethiopia. Developing Country Studies, Vol.6, No.10.

GRDC. (2009), Canola best practice management guide for southeastern Australia. Grains Research & Development Corporation.

Hashem, A, Wilkins, N and Piper, T. (2001a), 'Competitiveness of wild radish in a wheat-lupin rotation', Agribusiness Crop Updates. (2001). Department of Agriculture Western Australia.

Heather F. Sahli and Jeffrey K. Conner. (2007), Visitation, Effectiveness, and Efficiency of 15 Genera of Visitors to Wild Radish, *Raphanus Raphanistrum* (Brassicaceae), American Journal of Botany **94**(2): 203-209.

Hedberg I, Edwards S. (1995), Flora of Ethiopia and Eritrea. Vol. 7. The National Herbarium, Addis Ababa, Ethiopia. pp 660.

Hill MO. (1973), Diversity and its evenness, a unifying notation and its consequences. J. Ecol. 54:427-32.

Holm LG, Doll J, Holm E, Pancho J, and Herberger J. (1997), World weeds: Natural Histories and Distributions. John Wiley, New York, USA.

Holm LG; Pancho JV; Herberger JP; Plucknett DL. (1991), A Geographic Atlas of World Weeds. Malabar, Florida, USA: Krieger Publishing Company.

Horro Gudru Welega Zone Demographics, Wikipedia, the free encyclopedia "http://en. wikipedia.org/w/index. php", Assessed 16 March 2017.

Jones WA; Sullivan MJ. (1982), Role of host plants in population dynamics of stink bug pests of soybean in South Carolina. Environmental Entomology, 11(4):867-875

Kohli RK, Dogra K, Daizy J, Singh, RB. (2004), Impact of invasive plants on the structure and composition of natural vegetation of Northwestern India, Himalayas. Weed Technol. 18:1296-1300.

Kombiok J.M., Safo E.Y., Quansah C., and Safo C., Quansah and Ibana S. (2003), Assessment of weed infestation and economic returns of maize/cowpea intercrop under different tillage systems in northern Ghana, Savanna Agricultural Research Institute, CSIR, Tamale, Department of Crop Science, Faculty of Agriculture, Knust, Kumasi, Ghana.

Lee, Ted N. and Snow, Allison A. (1998), Pollinator Preferences and the Persistence of Crop Genes in Wild Radish Populations (*Raphanus Raphanistrum,* Brassicaceae). American Journal of Botany, 85(3): 333-339.

Lesley G. Campbell, Zachary Teitel, Maria N. Miriti, and Allison A. Snow. (2014), Context-specific enhanced invasiveness of Raphanus crop-wild hybrids: A test for associations between greater fecundity and population growth. *Canada Journal of Plant Sciences*, 94: 1315-1324. doi:10.4141/CJPS-2014-070

Ludwing JA, Reyonlds JF. (1988), Statistical Ecology. Wiley interScience, New York. p.111.

Madafiglio, GP. (2002), 'Population management of *Raphanus raphanistrum* L. (Wild radish) by regulating seed production', PhD Dissertation, University of Western Sydney.

Malik, Mayank. (2009), Biology and Ecology of Wild Radish (*Raphanus raphanistrum*). PhD Dissertation. P.386. Tiger Prints, awesole@clemson.edu. Follow this and additional works at: htp://tigerprints.clemson.edu/all_dissertations

McGeoch MA, Kalwij JM, Rhodes JI. (2009), A spatial assessment of *Brassica napus* gene flow potential to wild and weedy relatives in the Fynbos Biome. S Afr J Sci **105**: 109-115

*Mekonnen A, Haile A, Dessie T and Mekasha Y. (2012), On farm characterization of Horro cattle breed production systems in western Oromia, Ethiopia***.** Livestock Research for Rural Development. Volume 24,Article#100**.** *Retrieved November 10, 2020, from http://www.lrrd.org/lrrd24/6/meko24100.htm*

Murrumbidgee CMA. (Not Dated) Best Management Practices for Dry land Cropping Systems: Wild radish (*Raphanus raphanistrum*); www.murrumbidgee.cma.nsw.gov.au or www.dpi.nsw.gov.au/; accessed July 2017.

Naidu, V.S.G.R. (2012), Hand Book on Weed Identification. Directorate of Weed Science Research, Jabalpur, India pp 354.

Naceur Djebali, JohN K. Scott, Mireille jourDan and Thouraya Souissi. (2009), Fungi pathogeni**c** on wild radish

(*Raphanus raphanistrum* L.) in northern Tunisia as potential biocontrol agents**.** *Phytopathol. Mediterr* **48**, 205–213

Newman, P. (2003), 'The looming threat of wild radish', Agribusiness Crop Updates 2003, Department of Agriculture Western Australia.

Norsworthy, J. K. (2003), Allelopathic potential of wild radish (*Raphanus raphanistrum*). Weed Technol. 17:307-313.

Olana, Bezuayehu Tefera (2006), People and Dam: Environmental and Socio-economic changes induced by reservoir in Fincha Water shades, Western Ethiopia. PhD Dissertation, Wageningen University, Netherland.

Phil Maher, Peter Martin, Michael Michelmore, Andrew Storrie, Bob trounce, Birgitte Verbeek, Sally Vidler, and Steve Wingrave. (2004), Introductory Weed Management Manual, Australian Weed Management, department of Environment and the Heritage.

Ravi Sankar N, Md. N.S. Hasan, Temesgen Fita and Nagalakshmi Devamma M. (2014), Natural Occurrence of *Erysiphe cruciferarum*, the Causal Agent of Powdery Mildew Disease on *Raphanus raphanistrum* in Ethiopia; Proceedings of the National Symposium; Science, Technology and Innovation for National Development, 21 and 22 March, 2014 Wollega University, Nekemte, Ethiopia.

Reeves, T. G., Code G. R., and Piggin C. M. (1981), Seed production and longevity, seasonal emergence, and phenology of wild radish (*Raphanus raphanistrum* L.). *Australian Journal of Experimental Agriculture and Animal Husbandry* **21**, 524-530.

Rubin B; Benjamin A, (1983), Solar heating of the soil: effect on weed control and on soil-incorporated herbicides. Weed Science, 31(6):819-825.

Sakai AK, Allendorf FW, Holt JS, Lodge DM, Molofsky J, Baughman KA, Cabin S, Cohen, RJ, Allstrand JE, McCauley NC, O"Neil DE, Parker IM, Thompson JN, Waller SG. (2001), "The population biology of invasive species" Ann. Rev. Ecol. Syst. 32:305-332.

Seyed Vahid Eslami. (2006), Ecology of Wild Radish (*Raphanus raphanistrum*):Crop-weed Competition & Seed Dormancy. School of Agriculture, Food and Wine, Faculty of Science. PhD Dissertation. The University of Adelaide, South Australia. p156

Singh M. M. (2009), Biology and Ecology of Wild Radish (*Raphanus raphanistrum*) PhD Dissertation, Clemson University, pp 175

Sutherland, S. (1999), Weed management. In: Salisbury, P., Potter T., McDonald G., Green A.G., eds. Canola in Australia: the first thirty years. 10th International Rapeseed Congress Organizing Committee. Pp.59-66.

Warwick, S. I., Francis, A. and Mulligan, G. A. (1999), *Brassicaceae* of Canada. Agriculture and Agri-Food Canada. (1999). Updated version. [Online] Available: http://www.scib.gc. ca/spp_pages/brass/index_e.php; (Accessed, Jan. 07, 2017)

Warwick, S.I. and Francis, A. (2005), The biology of Canadian weeds. 132. *Raphanus raphanistrum*. Canadian Journal of Plant Sciences; 85: 709-733.

Wilson JR, Dormontt EE, Prentis PJ, Lowe AJ, Richardson DM. (2009), Something in the way you move: Dispersal pathways affect invasion success. Trends Ecological Evolution, 24: 136-144

Wittenberg R, Simons SA, Mauremootoo JR. (2004), Instrument and tools for assessing the impact of invasive alien species in Africa. Report Procedures under the PDF-B phase of UNEP GEF Project Removing Barriers to invasive plant Management in Africa. CAB. International. Nairobi, Kenya

Woolcock JL, Cousens R. (2000), A mathematical analysis of factors affecting the rate of spread of patches of annual weeds in an arable field. Weed Sciences, **48**:27–34.

Zahid Hussain, Fazal Munsif, Syed Ishfaq Ali Shah, Bakhtiar Gul1, Naeem Khan1, Siraj ud Din Kakar1 and Akhlaq Ahmad. (2012), Assessment of Weed Problems in Wheat crop of Peshawar Pakistan, Weed Sci. Res. **18**(3): 357-366.

Zakeri A; Banihashemi Z. (1996), The role of weeds in cultivated and virgin soils on activity and perpetuation of Fusarium oxysporum f.sp. melonis in Fars Province. Iranian Journal of Plant Pathology, 32(1/2):22-25 (En), 28-39 (Pe); 30 ref.

APPENDICES I : Partial waypoints of the study area

Type,C,10	Latitude	Longitude	Y_ Proj	X_ Proj	Altitude	Model,C,20
Waypoint	9.45859258	37.06399	1045936.459	287346.1580	2920	GPS60
Waypoint	9.56937997	37.36251	1058021.876	320188.0433	2296	GPS60
Waypoint	9.56938097	37.36251	1058021.986	320188.1262	2297	GPS60
Waypoint	9.56938097	37.36251	1058021.986	320188.1262	2297	GPS60
Waypoint	9.23210551	37.35918	1020720.064	319648.2534	2343	GPS60
Waypoint	9.23211364	37.35917	1020720.967	319647.4466	2340	GPS60
Waypoint	9.24743962	37.34770	1022421.872	318395.0878	2267	GPS60

Type,C,10	Latitude	Longitude	Y_ Proj	X_ Proj	Altitude	Model,C,20
Waypoint	9.24742352	37.34771	1022420.088	318395.8443	2267	GPS60
Waypoint	9.24742126	37.34771	1022419.838	318395.7882	2267	GPS60
Waypoint	9.24741942	37.34771	1022419.635	318395.7686	2265	GPS60
Waypoint	9.24741196	37.34771	1022418.807	318396.4284	2266	GPS60
Waypoint	9.24833078	37.34644	1022521.078	318257.2453	2256	GPS60
Waypoint	9.24833078	37.34644	1022521.078	318257.3464	2256	GPS60
Waypoint	9.24835618	37.34648	1022523.871	318260.7306	2257	GPS60
Waypoint	9.62372169	37.07637	1064195.500	288807.589	2612	GPS60
Waypoint	9.62371666	37.07639	1064194.933	288809.4357	2612	GPS60
Waypoint	9.62789931	37.07856	1064656.281	289050.5424	2579	GPS60
Waypoint	9.62797844	37.07857	1064665.028	289051.7508	2578	GPS60
Waypoint	9.65330855	37.08014	1067466.082	289240.2077	2510	GPS60
Waypoint	9.65500413	37.07995	1067653.765	289220.3304	2502	GPS60
Waypoint	9.66334521	37.08264	1068574.801	289520.3826	2527	GPS60
Waypoint	9.6820744	37.08955	1070642.369	290290.187	2548	GPS60
Waypoint	9.68225612	37.08961	1070662.433	290296.9786	2548	GPS60
Waypoint	9.68140519	37.08692	1070569.96	290001.2546	2564	GPS60
Waypoint	9.67997842	37.08511	1070413.245	289802.0266	2568	GPS60
Waypoint	9.67997842	37.08511	1070413.245	289802.0266	2568	GPS60
Waypoint	9.67894586	37.08273	1070300.495	289539.7382	2575	GPS60
Waypoint	9.67924677	37.08194	1070334.268	289453.5282	2575	GPS60
Waypoint	9.682091	37.07866	1070650.927	289095.2719	2578	GPS60
Waypoint	9.69116223	37.07094	1071659.183	288254.0973	2578	GPS60
Waypoint	9.69164168	37.07052	1071712.483	288208.1971	2578	GPS60
Waypoint	9.98512555	37.04416	1104195.256	285503.7309	2305	GPS60
Waypoint	9.9823876	37.05405	1103885.965	286587.0496	2373	GPS60
Waypoint	9.98221661	37.05498	1103866.45	286688.8191	2389	GPS60
Waypoint	9.98213388	37.05556	1103856.926	286751.9948	2397	GPS60
Waypoint	9.98240353	37.05573	1103886.641	286771.6297	2400	GPS60
Waypoint	9.98312437	37.02944	1103983.466	283888.4918	2387	GPS60
Waypoint	9.9831237	37.02944	1103983.39	283888.8873	2385	GPS60
Waypoint	9.96712424	37.03224	1102211.619	284185.0938	2371	GPS60
Waypoint	9.96649149	37.03369	1102140.674	284343.9341	2370	GPS60
Waypoint	9.9652705	37.04109	1102000.789	285154.9014	2358	GPS60
Waypoint	9.96403459	37.04141	1101863.861	285188.912	2361	GPS60
Waypoint	9.96241177	37.04151	1101684.275	285198.3573	2368	GPS60
Waypoint	9.96129831	37.04100	1101561.429	285141.8762	2373	GPS60
Waypoint	9.57689141	37.10996	1058994.697	292466.4005	2505	GPS60
Waypoint	9.57689183	37.10996	1058994.74	292467.0727	2506	GPS60
Waypoint	9.57689183	37.10996	1058994.74	292467.0727	2506	GPS60
Waypoint	9.57689183	37.10996	1058994.74	292467.0727	2506	GPS60
Waypoint	9.57884062	37.14564	1059189.01	296384.8821	2384	GPS60
Waypoint	9.57885596	37.14565	1059190.702	296385.7838	2383	GPS60
Waypoint	9.57885537	37.14565	1059190.637	296385.7198	2381	GPS60
Waypoint	9.5788516	37.14564	1059190.221	296385.4508	2382	GPS60
Waypoint	9.62099112	37.24486	1063794.178	307302.2569	2360	GPS60
Waypoint	9.62680338	37.24807	1064435.274	307657.334	2347	GPS60
Waypoint	9.62679089	37.24806	1064433.896	307656.6552	2345	GPS60
Waypoint	9.66936794	37.31472	1069106.498	314996.1757	2406	GPS60
Waypoint	9.60920189	37.34014	1062438.128	317754.0621	2387	GPS60
Waypoint	9.59854815	37.33855	1061260.612	317574.1555	2403	GPS60
Waypoint	9.60713281	37.33708	1062210.902	317417.3513	2382	GPS60