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Review on the Agronomic Management Practices of Garlic (Allium sativum L.)

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1. Introduction

Garlic (*Allium sativum L.*) belongs to the family of Alliaceae. Other crops in this family are Onion (*A.cepa* L.), Leek (*A. ameloprisum*), Shallot (*A. asacloncum* L) and Chile (*A. schoenoprasum* L). Garlic is the second most widely used of cultivated bulb crops after Onion. It is an erect annual herb that can reach a height of 75cm- 90cm and grows during dry and middle winter season (Brewster, 1994).

Garlic is believed to have originated in central Asia (India, Afghanistan, West China, Russia, etc) and spread to other part of the world through trades and colonization (Purse glove, 1972 and Tindall, 1986). According to FAO (2001), production of garlic stood at about 10 million tones per annual which is only about 10% that of bulb onion. China is the largest producer followed by South Korea. The world average yield of garlic is about 10 per hector, but it can go up to 19 per hector.

World garlic cultivation was increased from 771,000 ha of 1989/90 to 1,204, 711 ha of land in 2007 with total production from 6.5 million tones and productivity from 8.43tone per hector to 13.02 tones per hector respectively. While, in Ethiopia the total area under cultivation or production of garlic in 2006/07 reached 7,266 ha and the production is estimated to be over 683,000 quintals (MOARD, 2007).

It is rich in sugar, protein, fat, calcium, potassium, phosphorus, sulfur, iodine, fiber, and silicon, in addition it contains vitamins. It is pungent flavor makes it is used mainly as spices, seasoning and flavoring for food. Its medicinal value is also well recognized in the control and treatment of hypertension, worms, germs, bacteria and fungal disease, diabetes, cancer, ulcer, rheumatism etc.dehydrated garlic and extracts are fast replacing fresh bulbs for industrial and home usage in the production 0f drug, insecticide and explosives (Purse glove, 1972). According to Shanmugarelv *et al* (20010), this bulbs crop is another foreign exchange earner for India. Compound bulbs contain the edible products of these crops. A group of small segments or cloves is surrounded by a thin, white or pinkish sheath. The flavor of the cloves is stronger and pungent than other crops of bulbs. Garlic is different from onion in that in stead of producing one large bulb, it produces a group of small bulb called cloves. But seeds stalk is similar to that of onion and bears both seeds and bullets in the same head. The foliage of garlic is flattened rather than hallow like that onion. It is also grouped in the family alliaceous, a genus allium, because of its superior ovary. It was along time included in the family of liliaceous but was later shifted by some botanists to the family amaryllidaceous, as flowers are born on branched umbel on top of scalp. To prevent confusion the onion is placed now in the family alliaceae.

Production of the crop date back several decades in the state. The main producing local government areas are Goranya, Wurno, Gwa Wada awe and others where the crop is grown under irrigation during the cool dry season in November to murch.The traditional husbandry practices have resulted in 3-4 t/ha yield against the world average of 10-15 t/ha At off-season some quantity of garlic is usually sold at twice or three times the value of onions. It is mostly exported to other parts of Africa, Middle East Asia and Europe through various trade routes. A number of studies in various parts of the world have shown that garlic production can be improved though appropriate cultural practice (Anonymous, 1995)

Garlic is sensitive to moisture stress and high temperature and about 60% redaction in yield has been associated with water stress for this, it was envisaged that mulching, which offers a practical and reliable means of conserving soil water and regulation soil temperature, is likely to have advantageous effect on the growth and yield of this crop. Such affects might also be reflected in reducing cost of irrigation and ensuring sufficient management of the little water resource (Miko etal 2000).

There are numerous problem of garlic production accounted to low yield or reduction of yield. Some of these are level of fertilizer application, ways of weed management practice, irrigation and mulching. So as this reason, the aim of this seminar paper is to assess the agronomic management of garlic production related to the suitable control of about the problem.

2. Agronomic Management of Garlic production

2.1 Soils and climates

2.1.1 Soils

Garlic grows best on well drained soils high in organic matter sandy loam or loam soils have the most ideal texture for garlic Drought or excessively wet conditions will reduce Yields and marketable bulbs. Use of a green manure crop such as buck wheat tilled in a few weeks before planting is recommended to improve soil physical

properties. Well-composted manure applied and incorporated at a rate of 20 tons to 30 tones per acre has also been shown to be ideal as a soil amendment, especially on low organic matter soils, The optimum soil p^H is less than 5.8 Rates to apply should be well filled to provide a loose growing bed for bulb growth (Carl Rosen. 2011).

How ever, sandy, silt and clay loam are recommended for commercial production. The soil should be fertile rich in organic matter, well drained, capable of holding moisture during the growth period and having the p^H Soil ranging 6.8to7.2 lower p^H laves, inhibits plant growth and soil p^H below 5.0 can actually lead to plant death. In heavy soils the bulbs produced are deformed, and so they do not keep well storage .They get discolored in badly drained soil (Janet, 2008).

2.1.2 Climates

Almost it can grow a wide range of Climatic condition but prefer cool weather and grows at higher elevation from 900 to 1200m and grows best within the geographic area having a mean monthly growing temperature ranging from 12^0c to 24^0c .Inmost area elevation from 500 to 2000m provide suitable growing conditions, particularly during dry period .Relatively high temperature up to 30^0c is required for optimum bulb development but cooler condition in the early stage flavor vegetative growth. Excessive humidity and rein fall are detrimental to both Vegetative and bulb formation the crop is there fore normally grown in low rain fall areas with irrigation during the early vegetable growth. Extremely hot and long days are not conductive for the development of bulbs formation short day are very favorable for the formation of bulbs (Tindall, 19838).

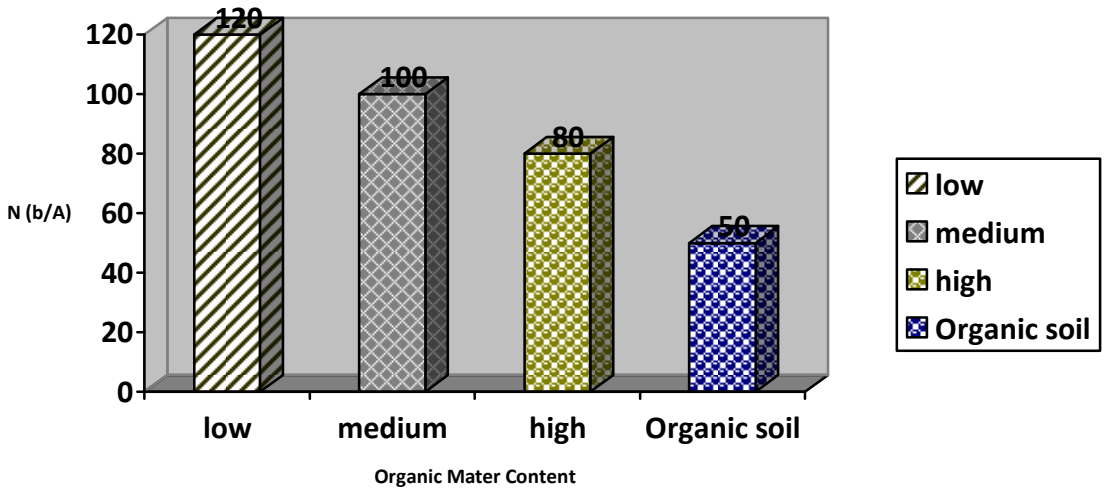
According to purse glove (1972) garlic is often planted in the late outman, so as to give vigorous growth in the warmer spring weather It is frost hardy and it can grown on a variety of soil and much of it is grown with irrigation Bulbing takes place during longer days and at high temperature, exposure to low temperature subsequent to bulb formation assists the process for this reason, garlic may fail to produce bulbs in the tropics, where it is usually grown at the higher altitudes, bolting does not seen to be influenced by temperature and some cloves never produce flower.

2.2 Fertilizer Requirements

Garlic grows well on fertile soil. N.P and K are referred to as the primary macronutrients. Because of the general probability of plant being deficient in these nutrients and the larger quantities taken up from the soil relative to other essential nutrients. The alliums species have low nutrients extraction capacity than most crop plants because of their shallow and unbranched roots system. The required and often respond well to additional fertilizer (Brewster, 1994).

Garlic (Allium SetivumL) has a moderate to high demand for Nitrogen (N) Recommendations for nitrogen are based on previous crop and organic matter content Reduce recommendation rates of nitrogen by 70lb nitrogen per acre (N/A) if the previous crops is alfalfa,40lb. N/A if the previous crop is clover, and 201b.N/A if the previous) crop is soybean or peas Additional of N may not be needed in the spring if adequate amounts of compost have been applied in the fall symptoms of N deficiency include a yellowing of older leaves and leaf tips, general yellowing of the plant poor vigor, thin stems, and low yields but sufficient N of garlic are dark green and high yields (Carl Rose,2011).

Fig 1 Nitrogin Recomendation for gRLIC



Balanced fertilization increases garlic yield in Anhui, field experiments with garlic show that rational use of

potassium (K) greatly promoted garlic growth and yield. Balanced fertilization is shown to improve crop values by large margin, with farm income being enhanced considerably. High yield garlic crop demands large amounts of nutrients especially N and K. Garlic is particularly sensitive to low soil K supply. Based on traditional practice, garlic grower in south west china tends to rely on fertilizer source that contain only N and P resulting steadily declining available soil K levels. Potassium up take imbalance relative to N can predispose the crop to serious disease and insect damage. All P and K were applied basally with 60% of the N. The remaining N was to P dressed at mid season. The local variety laian white garlic was sown at the end of September at a density of 600,000 plants /ha (Lujiu et al, 2004).

Potassium had an obvious growth promoting effect on garlic. Plant height, number of leaves, stem circumference, to P growth weight per plant substantially increased with N and K. The majority of highest value resulted with N,P_2O_5, K_2O rates of 375; 90; 30 kg/ha. Field notes indicate that the leaf color was more vibrant, plant growth was vigorous and robust and garlic shoots and cloves were visually larger when K was supplied.

Table 1 NPK treatments on growth characteristics of garlic, Anhui

Treat-ments	Plant height(cm)	Number of leaves	Stem circumference(cm)	Shoot length(cm)	Shoot diameter(cm)	Shoot weight	Height of top growth	Clove weight
$N_{300}K_0$	77.6	4.30	3.66	39.0	0.47	8.0	46.6	13.0
$N_{300}K_{150}$	88.0	5.16	4.43	59.1	0.64	14.7	68.7	16.0
$N_{300}K_{300}$	91.4	5.23	4.66	64.0	0.69	16.6	80.0	17.5
$N_{375}K_0$	83.3	4.56	3.80	40.8	0.51	9.3	53.6	13.8
$N_{375}K_{150}$	88.6	5.20	4.43	59.0	0.65	14.6	73.5	16.5
$N_{375}K_{300}$	93.3	5.30	4.60	63.8	0.70	15.6	82.0	16.3

Source: Lujiu et al, 2004

Fresh bulb yield of garlic during 1997 and 1998 and combined analysis as affected by the treatments. Application of increasing rates of nitrogen had significant effect on fresh bulb yields. It was observed that in 1998 and combined increasing levels of nitrogen from O to 120kg/ha resulted in significant increase in fresh bulb yield. Further increase to 240kgN/ha reduced the yield. The highest fresh bulb yield of 8.4ton/ha was recorded with 120kgN/hain 1998. Application of varying of rate of phosphorus had no significant impact on fresh bulb yield during the two seasons and combined analysis. (Kilgore et al., 2007)

Table 2 fresh bulb yield of garlic (kg/ha) application of rate of N and P during 1997 and 1998 seasons and combined analysis at stokoto.

	Fresh bulb yield		
Treatments	1997	1998	combined
N(kg/ha)			
0	8131	4416b	6273b
60	7522	8047a	7785a
120	8140	8364a	8243a
180	7811	6658a	7234ab
240	7289	7271a	7280ab
Significant	ns	**	*
LCD	1567	2162	1321
P(kg/ha)			
0	7698	6430	7064
22	7429	7376	7403
44	8208	7048	7628
Significant	ns	ns	ns
LCD	1224	1675	1023
Interaction			
N*P	ns	ns	ns

Source: (kilgori et al., 2007

Means in a column followed by same letter (s) within a treatment group are not significantly different. *, ** =significant at 5% and 1% level of probability respectively.

As with crop growth, increasing the k application significantly raised yield. At shuikou, under the low N rate K increased shoot yield by 120 to 156% and clove yield by 45 to 71% compared to zero k control (farmer practice). Potassium used in combination with the higher N rate produced 103 to 137% higher shoot yields and 11 to 36% higher clove yields. At xin'ian the range of yield increase for all treatments was 18 to 33% for shoots and 38 to 56% for cloves on paddy soil, and 24 to 29% (shoots) and 35 to 43% (cloves) on dry land (Lujiu et al., 2004).

Table 3 Garlic yield response and economic benefit from NPK application Anhui

		Yield increase						
		Yield t/ha		yield t/ha		%		
Site	treatment1	shoot	clove	shoot	clove	shoot	clove	income
Shoikou	$N_{300}K_0$	2.11	4.53	-	-	-	-	-
	$N_{300}K_{150}$	4.66**	6.55**	2.55	202	121	45	647
	$N_{300}K_{300}$	5.39**	7.79**	3.28	3.22	156	71	908
	$N_{375}K_0$	2.31	5.39	-	-	-	-	-
	$N_{375}K_{150}$	4.69**	6.00*	2.38	0.61	103	11	449
	$N_{375}K_{300}$	5.24**	7.35**	2.93	1.96	127	36	699
Xin'an -1	$N_{300}K_0$	6.99	9.30	_	_	_	_	_
(paddy	$N_{300}K_{150}$	8.27**	13.1**	1.28	3.84	18	41	666
field)	$N_{300}K_{300}$	9.15**	14.5	2.16	5.20	31	56	969
	$N_{375}K_0$	7..50	10..3	--	--	--	--	--
	$N_{375}K_{150}$	9.56**	14.3**	2.06	3.93	28	38	801
	$N_{375}K_{300}$	9.96**	15.3**	2.46	5.00	33	48	946
Xin'an -2	$N_{300}K_0$	7.06	10.4	_	_	_	_	_
(dry land)	$N_{300}K_{150}$	8.80**	14.0**	1.74	3.63	25	35	714
	$N_{300}K_{300}$	9.10**	14.8**	2.04	4.40	29	43	858
	$N_{375}K_0$	7.46	11.4	_	_	_	_	_
	$N_{375}K_{150}$	9.26**	15.5*8	1.80	4.14	24	36	786
	$N_{375}K_{300}$	9.63**	15.8**	2.17	4.40	29	49	876

1 Phosphorus was supplied at 90kg P_2O_5/ha
**, ** different significant at 5% and 1% level respectively.*

2.3 Mulching

Garlic roots and shoots can tolerate freezing conditions provided that sudden drops in temperature do not occur. There fore, within three to five weeks after planting, rows should be covered with a three-inch to four-inch layer of weed seed-free straw mulch to moderates in the winter and minimize excessively fluctuating temperatures in the winter and early spring. This mulch also will help control weeds during the growing season.

Mulch can be removed in the spring after the threat of hard freezes is over, generally the second week of April. Garlic shoots can tolerate air temperatures as low as 20°F without damage. Plant death, multiple shoots, and poor bulb development may occur if bulbs and shoots are exposed to temperatures below 10°F some growers remove the mulch completely in the spring to allow the soil to warm faster and then return the mulch after the shoots are about six inches tall; others will leave the mulch in place to minimize weed pressure and conserve moisture (Carl Rosen, 2011).

2.4 Irrigation

Garlic has relatively shallow root system and is sensitive to dry soil conditions. The amount of Water to apply will depend on soil type. Irrigation is essential on sandy soils and may be beneficial In some years on finer textured soils. Enough irrigation should be provided so that the available water holding capacity does not drop below about 50 % .The most critical stage for irrigation is during bulbing (mid-may to late June or July). Lack of irrigation or rainfall during this stage will result in smaller bulbs and earlier maturity. Irrigation should be

stopped about two weeks before harvest to avoid stained bulb wrappers and diseases. (Jerry Wright, 2011).

According to Rai and Yadev (2005), First irrigation is given so on after sowing and later field is irrigated after 10 to 15 days until bulb begin to develop. At this stage, more frequent irrigation. There should not be scarcity of moisture in the growing season to have best bulb development, other wise; the development of the bulbs will be checked as a soil may be packed around the base which interferes with their normal expansion. Irrigation after Temporary set back during bulb development causes the partially developed cloves to form tops. The last irrigation should be given 3 days before harvesting for making it easy with out damaging the bulbs. It can be irrigated either flooding in basin or border strips.

A soil available water hold in capacity (AWHC) obtained from the local soil and water conservation District office or country Soil survey in Minnesota.

Table 4. AWHC for several Minnesota Soils

Soil texture	**AWHC**	
	Inches/inch of soil	Inches/foot of soil
Loamy fine sand	0.08-0.12	0.96-1.44
Sandy loam	0.10-0.18	1.20-2.16
Loam	0.14-0.22	1.68-2.64
Silt loam	0.18-0.23	2.16-2.76
Clay loam	0.16-0.18	1.92-2.16

Source; Jerry Wright 2011

The average weight per bulb was notably reduced with the lowest N rate, but not affected by irrigation regimes. So, average across N fertilization treatments, bulb weight per 5ft sub plots was less with higher rate of irrigation treatments and no significant difference were found in weight per bulb.

Table 5 Yield data for irrigation treatments applied in 1999.

Data are averages of 6 field replication. Data are averaged across fertilization treatments.

Treatments	Applied water,% evaporate	Irrigation cut of date	Bulb count*	Bulb weight (kg)*	Piece weight(g/bulb)
T1	110	10 may	117.3	6.75	58.0
T2	110	24 may	113.0	6.36	61.1
T3	130	10 may	104.8	5.92	57.0
T4	130	24 may	111.4	6.15	55.3
LSD	-	-	ns	0.53	ns

Source; Anonmous, 1995

- Bulb count and weight are based on 5-ft sub plots.

2.5 Weed management

Garlic is a poor competition with weeds, unless weeds are controlled early, they can easily overtake young garlic plants, causing several yield losses. For conventional garlic production, application of Round up ™ in late August or early September, before planting garlic in the fall, is recommended if perennial weeds are a problem. Use of a green manure crop, such as buck wheat plowed down before going to seed, will reduce annual weed competition. Leaving the straw mulch in place will greatly reduce weed pressure. If mulch is removed in the spring to allow the soil to warm up, a thorough, shallow cultivation before reapplying straw much will keep down annual weed populations. Be sure to use straw free of weed seed as mulch. If desired, a few sol applied and post emergence herbicides are registered for use on garlic production (Rai and Yadav, 2005)

Weed management studies in garlic crop were conducted during 2000-2001 and 2002-2003at the National Agricultural Research Center. During the first year, pendimenthalin was sprayed at 0.80a.i.ha^{-1} Pre emergence two days after first irrigation in moist condition followed by different mechanical weeding regimes. During second year, pendimenthalin, oxadiazon, glyphosate and metribuzin were sprayed at 0.801, 0.251, 0.61 and 0.45kg.a.i.ha^{-1}, respectively, pre emergence two days after first irrigation in moist condition followed by one hoeing at 80 days after herbicide application. Herbicide treatments were compared with weed free and weedy check. The most dominant weed Spp Phalaris minor, Cronopus didymus, Medicago denticulata and Rumex dentatus. All herbicide followed by hoeing except metribuzin gave bulb yield at par with weed free treatment. Metribuzin resulted in minimum bulb yield (0.59tha^{-1}) because of its extreme phytotoxicity to garlic crop, which resulted in survival of a few plants. Pendimenthalin in combination with manual hoeing gave high yield and monetary returns (Mehmood *et al*, 2006). Germination percentages in all treatments indicate that or were recorded after 15 days of sowing. The germination varied from 81% to 89% during 2000-2001 and 81% to 94% during 2002-2003. However, there was no significant difference in germination percentage in all treatments during both years. These results indicate that pre emergence application of all herbicides did not affect the germination of the garlic crop, but not in case of metribuzin as shown in the following table.

Table 6. Yield and other parameters of garlic crop as affected by different weed control method in garlic crop (2000-2001).

Treatments	Germination (%)	Fresh biomass of weed kgm^{-2}	No. of bulbs(m^2)	Average bulb weight(g)	Yield (tha^{-1})	Yield increase over weedy check 9tha^{-1})	Percent increase
Pendimenthalin alone	88.67^{NS}	1.000 b	30.18 a	29.86 b	7.29 b	4.12	130
Pendimenthalin +1 hoeing	86.67	0.054 c	31.93 a	42.30 a	13.38 a	10.21	322
Pendimenthalin +2 hoeing	86.67	0.020 c	32.58 a	42.66 a	13.83 a	10.66	336
Pendimenthalin +3 hoeing	85.00	0.010 c	32.58 a	43.49 a	14.17 a	11.00	347
Weed free	84.67	0.010 c	31.08 a	42.39 a	12.21 a	9.04	285
Weedy check	81.00	3.290 a	15.83 b	21.36 c	3.170 c	-	-

Source: - Mehmood *et al*, 2004.

Values followed by the same letters in the respective column do not differ significantly at 5% level of significance according to DMR test.

Table 7. Yield and other parameters of garlic crop as affected by different weed control methods in garlic crop (2002-2003).

Treatment	Germination (%)	Fresh biomass of weeds kgm^{-2}	Average bulb weight (g)	Number of bulbs m^2	Yield (tha^{-1})	Yield increase over weedy check (tha^{-1})	Percent increase
Oxadiazon +1hoeing	84.07^{NS}	0.467 b	29.25 a	30.26 a	8.85 a	7.32	479.57
Glyphosate +1hoeing	83.52	1.067 b	26.67 a	27.74 a	7.39 a	5.87	384.41
Pendimenthalin +1hoeing	80.81	0.733 b	31.97 a	29.74 a	9.51 a	7.98	522.79
Metribuzin +1hoeing	87.04	0.801 b	29.50 a	2.0 c	0.59 b	-0.93	-61.17
Weed free	84.44	0.333 c	31.03 a	30.94 a	9.60 a	8.073	528.68
Weedy check	87.04	3.100 a	12.52 b	12.20 b	1.52 b	-	-

Source: - Mehmood et. al, 2004.

Values followed by the same letters in the respective column do not differ significantly at 5% level of significant according to DMR test.

In all weed control treatments, higher bulb weight was recorded as compared to weedy control during both years (Tables 4 and 5).During 2000-2001, significantly less bulb weight (29.86g) was recorded in the treatment where pendimenthalin alone was used followed by no hoeing. The minimum bulb yield (0.59tha-1) was recorded when metribuzin at 0.45kga.i.ha-1 was used (Table 5). This lowest yield due to extremely phytotoxicity of metribuzin to garlic crop and bulb yield (7.29tha-1) was recorded in the treatment where pendimenthalin alone was used followed by no hoeing (Table 4). However, pendimenthalin suppressed weeds growth for approximately a period of two months but later on, the weed began to flourish and competed with crop resulted in lower yield (Mehamod, 2004).

2.6 Harvesting

Allium Stivum L. Is a crop of 4 ½ to 5 months duration, when the leaves start turning yellowish or brownish and show signs of drying up (usually about a month of or so far the emergence of seed Stalks) the crops is ready for harvest. The plant are then pulled out or uprooted with a country plough and are field in to small bundles which are then kept in the field or in the shade for two to three days for curing and drying so that the bulbs become hard and their keeping quality prolonged. The bulbs may be stored by hanging them on bamboo sticks or by keeping them a dry sand on the floor in well ventilated room (shanmugavelv et at, 2010).

Harvesting early result in small bulbs that do not stored well. Harvesting too late will force the clove to pop out of the skins, making them susceptible to disease and resulting in UN marketable size bulbs. To harvest, the bulbs should be dug with the roots and shoots still attached. At this point there is some controversy about whether the bulbs should be washed or not. If the soil is not wet at harvester if the garlic is grown on sandy soils, it is generally not necessary to wash the bulbs (Rai and Yadav 2005).

According to ATTRA(2001) but begin to mature four to six month in temperate and four months in tropics at planting. The garlic, plants ready for harvest when the Tops begin to dry out and collapse at this time irrigation is stopped one two weeks before harvesting, as it is easier to pull or dig garlic out of dry soil then mud and will store bitter and the indicator of maturity are softening of the main stem above the bulb and yellowing of 75% of level.

3. Summary and Conclusions

Generally garlic grows best on well drained soil and high in organic matter content Sand, silt and clay loam soils are recommended for commercial production. This bulb crops can adapt wide range of climatic condition best prefer cool season grows at high elevation. The rational use of potassium greatly promoted garlic growth and yield and it had an obvious growth. The majority of highest value resulted with N, P_2O_5, K_2O rate of 375, 90, 30kgha^{-1} respectively.

The average weight per bulb was not ably reduced with the lowest nitrogen rate, but not affected by irrigation regimes. All herbicides followed by hoeing except metribuzun gave bulb yield at par with weed free treatment. Metribuzin result minimum bulb yield because of its extreme phytotoxicity; however, pndimenthalin suppressed weeds growth for approximately a period of two months, but later on the weed began to flourish and compete with crop in lower yield. Garlic has four to six months duration to harvest, early harvesting resulted in small bulbs that do not store well, while too late harvesting will face the clove to pop out the skin and the results are unmarketable size bulbs.

4. Prospects

- ✓ Agro –climatic suitability (soil and climate) and rich water source for diversified irrigation is required.
- ✓ Promoting availability of market for both local and export of this crop
- ✓ Improving production technology and appropriate post harvest technology.
- ✓ Increasing the knowledge of society about the medicinal, nutritional and economical values of the plants in both urban and rural areas as the grown in home garden as well as in field is required.
- ✓ Maximizing Research done about the management of garlic production spatially in our country is required.
- ✓ Teaching the society how to use fertilizer,mulching,weed management and anthers managements for garlic production is required
- ✓ Promoting strong working collaboration for garlic production is required

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