WEED CROP COMPETITION

DEFINITION

Competition comes from Latin word competere, which means to ask or sue for the same thing another does. Competition is a question of the reaction of a plant to the physical factors that encompass it and the effect of these upon adjacent plants. In the exact sense, two plants no matter how close, do not compete with each other so long as the water content, the nutrient material, and the light are in excess of the needs of both (Zimdahl, 1998).

Competition occurs when the immediate supply of the factors or things is below the combined demand of the two or more competing organisms. This definition makes competition different from the broader term interference that includes competition, allelopathy, biotic interference and other environmental modifications. Competition is for some thing in limited supply. Competition of weeds with crop reduces yields severely.

More loss occurs from weeds than from insects or fungi, this is because fungi and insects are not always present but crops always have weeds. General rules are:

1. Competition tends to be greater between plants of similar soils, water, nutrient, and climatic requirements.
2. Competition is most serious when the crops are young, i.e., within the first 4 to 8 weeks after germination.
3. Weeds of similar growth habit to the crop plants are often more serious competitors than weeds of dissimilar habit thus broad-leaved weeds usually decrease yields more in broad-leaved crops, and grass weeds are more serious in grass crops although this is not meant to imply that broad-leaved weeds are not important in grass crop and vice versa. Root systems and growth habits are likely to be similar in related plants and thus cause greater competition than will occur between plants of distinctly different growth habits.
4. The first plants to occupy any areas of soil, small or large, tend to exclude others.
5. A moderate weed infestation sometimes is as serious as a heavy infestation.
6. Weeds compete for water, nutrients, space and light, but may also release toxins in soil which inhibit crop growth.

TYPE OF COMPETITION

There are two types of competition which exist in field.

1. INTRA SPECIFIC COMPETITION

It is the competition between the plants of same species which may be of crop or weed. As the plants (of crop and weed) grow in age, due to mutual competition their number per unit area decreases which is due to self induced thinning. Competition within plants of the same species for instance *Phalaris minor* is called intra specific competition.

2. INTER SPECIFIC COMPETITION

It is the competition between two or more plants belonging to different species. In other words, inter-specific competition is competition of crop with associated weeds and it has more bearing on agricultural crops. Competition within weeds belonging to different species is also included in this category. Aggressive species may dominate in competition due to early germinating habits, quick growing rates during initial growth stages, tall growing habits, more leaf area, extensive root system, more spreading habits and high seed production rates (Walia, 2003).

FACTORS AFFECTING WEED CROP COMPETITION

Factors (Anonymous, 1996) which determine the vigour and competitive ability of crop plants, weeds and the density of the stands are:

A. CROP FACTORS

1. CROP SELECTION

Within a rotation, the competitive ability of crops varies greatly. Comparatively tall and fast canopy forming crops suffer less weed competition than the slow growing and short stature ones. Among the winter grains, barley has high tolerance of competition to weeds than wheat, oat, canola, and lentil. Barley has ability to develop more extensive roots during its initial three weeks growth period. Pulse crops, like lentil, are poor competitors against weeds. Canola offers poor competition to weeds in the seedling stage, but can be effective once it becomes established. Lucerne, which has large deep root system and is a vigorous crop, competes with deep rooted weeds such as annual thistle. Therefore, planting competitive crops with root systems that are similar to the weeds can reduce weed numbers. The converse is also true and the crops that are not vigorous and poor competitors will be out competed by weeds with similar root systems.

2. CROP VARIETY

Within any specific crop many varieties exist. The use of cultivars that achieve canopy closure early, or that have a more competitive architecture (taller or have more tillers) should be considered. Moreover, it is important to choose a variety of the crop plant which is well adapted to local conditions of soil, water and climate. Poorly competing crop plants are generally much more easily infested with a variety of weeds. Introduction of higher yielding but less competitive varieties is of little or no value unless the weeds can be controlled. Many of the new potentially high yielding grain varieties (wheat, rice) are short statured (dwarf, semi dwarf) which do not compete well, especially with the taller weeds because of their initial slow growth. Weed control is vital in these crops if the full yield potential is to be achieved. A vigorous variety can give a temporary competitive advantage over weeds, but this advantage is lost in the absence of timely and proper control measures.

3. CROP MIXTURES/POLY CROPS

Mixing two or more cultivars of the crop or mixing two or more different crops together, e.g., a cereal and a bean can increase the competitive ability of the crop by filling different environmental niches, for example if two broad acre crops such as peas and cereals are grown together one of which is shallow rooting and the other deeper rooting they will compete against both deep and shallow rooting weeds, whereas if only one crop was grown it would not effectively compete in the root zone against weeds with a different root habit so those weeds will grow more vigorously.

4. DATE OF SEEDING

The date of seeding affects the vigour of crop plants, because it is the main factor determining the composition of weed flora. If seeds can be planted early and germinate before the weeds do, this will give the crops an advantage. In the case of cereals early seeding has consistently produced the most competitive crop with the highest yields. Conversely, if the date of seeding can be delayed until most of the weeds have germinated, they can be killed before planting the crop. In this situation tillage should begin early, in an attempt to warm the soil and stimulate weed growth. The number of tillage operations that can be performed will depend on the soil type, moisture conditions and crop to be planted. In practicing delayed seeding, it is important that crop maturation, quality and optimum yield are not unduly sacrificed or put at risk.

5. SEEDING RATE

Increasing seeding rates 20-30% above normal can increase the competitive ability of a crop. Provided moisture conditions are adequate, higher seeding rates will also result in earlier maturity (2-3 days), shorter plant height, reduced tillering and possibly higher yields.

Green feed and silage crops should be seeded at higher rates to increase crop competition and feed quality. Increased seeding rates should also be used where either post-seeding or post emergence tillage is planned. This will help compensate for any damage caused by the in-crop tillage. Khan and Rashid (1989), Marwat *et al.* (1989) and Awan *et al.* (2004) reported decrease in weed biomass with an increase in the seed rate in rapeseed mustard, wheat and rice, respectively (Tables- 4,5 & 6).

Table-4 Effect of Seeding Rate on Weed Density and Weed Biomass in Rapeseed and Mustard

Seeding rate (kg ha^{-1})	Weed density (No. m^{-2})	Weed biomass (g m^{-2})	Seed yield (kg ha^{-1})
4	136.5	63	1044
6	134	51.8	1154.5
8	89.5	47	1080
10	70	35.4	1052

Khan and Rashid (1989)

Table-5 Effect of Seed Rate on Fresh Weight of Weeds Four Months After Sowing Of Wheat

Seed rate (kg ha^{-1})	Fresh weight of weeds (g m^{-2})
80	612.95
100	502.83
120	459.76

Marwat *et al.* (1989)

Table-6 Effect of Different Seeding Rates on Dry Weed Biomass and Paddy Yield In Direct-Seeded Rice 45 Days after Sowing

Seeding rate (kg ha^{-1})	Dry weight (g m^{-2})	Paddy yield (kg ha^{-1})
60	99.92	6.22
90	98.14	6.45
120	88.29	7.18

Awan *et al.* (2004)

6. ROW SPACING

In general, narrow row spacing in cereal, pulse and most oilseed crops offer the best competitive advantage against weeds. From a crop-weed perspective, any system which places seeds equal distance apart is the ideal arrangement. This allows plants an equal opportunity to compete for water and nutrients. In addition, there is less open space for weeds to grow. Less competitive crops, such as lentil, will tend to benefit most from narrow rows. Khan *et al.* (2002) recorded decrease in weed biomass with decrease in row spacing of rice (Table-7).

Table-7 Effect of Plant Population of Rice on Weed Biomass and Paddy Yield

Spacing (cm)	Plant population ha^{-1}	Weed biomass $g\ m^{-2}$	Paddy yield $kg\ ha^{-1}$
15 x 15	4,44,444	15.43	5667
20 x 20	2,50,000	60.91	7129
25 x 25	1,60,000	89.26	7208
30 x 30	1,11,111	213.20	6369

Khan *et al.* (2002)

7. SEEDING DEPTH

Optimum seeding depth will vary between crops. This will depend on seed size, soil type and moisture conditions. Seeding depth should be no deeper than required to achieve a quick and even emergence. This will ensure the optimum competitive ability between the crop and weeds. Pre-seeding tillage operations should be as shallow as possible. Deep tillage will result in excessive soil moisture loss and make seeding at a uniform depth difficult. If the soil is loose, consideration may be given to packing prior to seeding. This will firm the soil and help bring moisture closer to the soil surface.

8. CROP DENSITY

The plant population influences the competitive relationship between crop plants and weeds. Increasing plant population decreases the weed growth and thereby reduces the competition. Khan *et al.*, (2002) stated that there was an increase in weed biomass with decrease in plant population of rice (Table-7)

9. SOWING METHOD OF CROP

Proper seeding depth, better crop stand and growth is attained in the early period through mechanical seeding method and ultimately weeds are suppressed. Weed densities and weed biomass (Table-8) were less but seed yield was more in mechanical line seeding as compared to broadcast seeding method (Khan and Rashid, 1989).

Table-8 Effect of Seeding Methods on Weed Density, Weed Biomass and Yield of Rapeseed and Mustard

Seeding method	Weed density (No. m^{-2})	Weed biomass (gm^{-2})	Seed yield (kg ha^{-1})
Broadcast seeding	131	59	839.50
Mechanical row seeding	84.50	40	1300.3

Khan and Rashid (1989)

10. CROP ROTATION

Alternating row crops and broadcast crops, is advantageous in reducing the weed stands because it varies the type of tillage and alternates the season of the year and that the land is densely covered with plant growth. When crops with different production requirements are included in a rotation they keep down the weed growth by not allowing a build-up of weeds ecologically adapted to one crop.

Common rotation	Suggested rotation for weed control
Wheat-rice	Berseem-rice
Wheat-rice	Wheat-Jute/sorghum
Wheat-cotton	Wheat-rice
Wheat-maize	Wheat-rice

B. SOIL FACTORS

1. SOIL FERTILITY

The fertility of the soil affects both the vigour of the crop plants and the vigour of weeds. Many weeds can utilize fertilizers as well as or better than the crop plants. However, if most of the weeds can be stunted or destroyed by cultivation or sprays, the extra vigour that fertilizers impart to crop plants makes them better competitors. Placement of the fertilizer directly on the furrows appears to have advantages over broadcast fertilization because it makes the fertilizer directly available to the crop.

It is important that an imbalance of any nutrient does not occur. A balance of nutrients assures optimum crop emergence and healthy plants. At higher levels, or an imbalance favouring higher levels of nitrogen, weeds like *Avena fatua* are generally more competitive than a crop (wheat, barley). Soil available nitrogen, particularly in the ammonia form, stimulates the germination of *A. fatua* (Anonymous, 1996). Application of nitrogen benefits *Cyperus rotundus* more than rice. *Echinochloa crus-galli* may be stimulated to grow where high levels of phosphate occur (Michael, 2003). An imbalance of nutrients can readily occur where large applications of manure have been applied. Soil testing should be conducted on a regular basis to monitor nutrient levels and allow a correction of any imbalances.

2. SOIL MOISTURE

The moisture variations in soil may also influence the course of weed competition. Weeds are adapted to grow well and compete with the crops, both in moisture stress and ample moisture conditions. This is so because there are different species of weeds available suited to highly variable moisture conditions. Irrigation at moisture stress conditions may benefit crops more than the weeds, yet it all depends upon the weed-crop situation at the time of irrigation. When the weeds are already present, the irrigation favours luxuriant growth of weeds which completely over power the crops. However, if the crop is irrigated after it has grown 15 cm or taller in a weed-free environment, irrigation could hasten crop growth, thus suppressing the weeds.

3. SOIL TILLAGE

Tillage helps in uprooting germinated seedlings while it also helps in bringing seeds from lower depths to upper soil surface. The seed which have germinated with pre-sowing irrigation can be killed with tillage during preparation. In this way weed menace can be minimized. Control of weeds by tillage depends on type of tillage implements and soil conditions. Marwat *et al*., (1989) and Khattak *et al*., (2005) obtained best weed control with moldboard plow, and moldboard + rotavator in wheat and maize, respectively (Tables- 9 & 11). On the other hand Mann *et al*., (2004) advocated zero tillage technology for suppressing weeds as compared to conventional tillage for wheat in rice-wheat system (Table-10).

Table-9 Effect of Land Preparation on Fresh Weight of Weeds Four Months After Sowing Of Wheat

Treatment	Fresh weight of weeds (gm^{-2})
Zero tillage	739.00
Moldboard plough	318.57
Cultivator	563.51
Disc plough	378.51
Local plough	626.40

Marwat *et al*. (1989)

Table-10 Effect of Conservation (Zero) Tillage and Conventional Tillage on Weeds of Wheat before First Irrigation in Rice-Wheat Cropping System

Tillage method	Weed density m^{-2}
Zero tillage	18.33
Conventional tillage	28.50

Mann *et al.* (2004)

Table-11 Effect of Various Tillage Treatments on Number of Weeds in Maize

Tillage treatments	Weed density m^{-2}
Cultivator two times	140
Cultivator four times	154
Cultivator six times	136
Moldboard plow once and rotavator once	133
Moldboard plow once and disk harrow once	134
Moldboard plow once and disk harrow two times	140
Disk plow once and cultivator two times	138

Khattak *et al.* (2005)

4. SOIL REACTION

Abnormal soil reactions (very high or very low pH) often aggravate weed competition. This is because of the fact that specific weed species suited to different soil reactions exist in the environment while our crops grow best only in a specified range of soil pH. As such, weeds offer more intense competition to crops under abnormal pH soils than in the normal pH soils.

C. CLIMATE

Climate influences the species composition and density of weeds in an environment. The adverse weather conditions like drought, excessive rains, and extremes of temperature, will favour weed growth since most of our crop plants are susceptible to climatic stresses. This becomes still worst when crop cultivation is done under marginal lands where crop is grown far from their optimum requirements.

D. WEED FACTORS

1. RAPIDITY OF GERMINATION AND SUBSEQUENT GROWTH

Many weeds are prolific producers of seeds which remain viable or dormant in the soil depending on the adaptive mechanism used. When the soil is disturbed by tillage, weed seed germination takes place and the weeds emerge even before or along with the emergence of crop plants. The plants that germinate first and grow fast tend to exclude others. The first plant to occupy an area has an advantage over late comers. If weeds emerge after the crop is well established, they may not pose as serious a problem as those which emerge before the crop plants emerged and established. In crops like surgarcane where the germination phase takes a month, the weeds take advantage and grow vigorously as they are able to germinate from third day onwards. In general, when the time of germination of a crop coincides with the emergence of first flush of weeds, it leads to intense weed crop competition.

2. WEED SPECIES INFESTING THE AREA

The degree of weed competition is determined by the weed species infesting the area. For example, an annual grass *Echinochloa colonum* is a more severe competitor than another annual grass *E. crus-galli*. *Avena fatua* is more competitive in wheat than other weeds.

Weeds differ in their ability to (Tables-11 & 12) compete with crop at similar density levels. This is primarily because of differences in their growth habits affecting the germination and growth of neighbouring crop plants. In dry areas, perennial weeds like *Cirsium arvense* and *Convolvulus arvensis* have been found more competitive than the annual weed species because of their deep roots and early heavy shoot growths. Because of such differential competitive abilities of different weed species, it has been further established that for similar weed densities, a composite stand of weed species is always more competitive to crop than solid stand of a single weed species. Saeed *et al.*, (1978) reported maximum wheat grain yield reduction by *C. album*. In rice *Fimbristylis littoralis* caused maximum reduction in grain yield (Shad and Khan, 1988), but a composite stand of weeds caused more reduction than that by single weed species (Tables-12 & 13).

Table-12 Wheat Grain Yield Due To Full Season Competition with Various Weeds

Weed	Grain yield (kg ha^{-1})	Decrease over weed free (%)
Weed free	3604	-
Chenopodium album (23 ft^2)	3026	16.04

Carthamus oxyacantha (7ft^2)	3260	9.54
Asphodelus tenuifolius (14ft^2)	3362	6.71
Sorghum halepense (1 ft^2)	3475	3.58
Cyperus rotundus (17 ft^2)	3510	2.61
Euphorbia helioscopia (7 ft^2)	3362	6.71

Saeed *et al.* (1978)

Table-13 Comparative Effect of an Individual Weed on the Paddy Yield of Transplanted Rice (Basmati-370)

Weed species	**Paddy yield (t ha^{-2})**	**Decrease over no weed (%)**
Fimbristylis littoralis	2.70	28.95
Echinochloa crusgalli	2.90	23.68
Sagittaria guayensis	3.32	12.63
All weeds present	2.02	46.84
No weed	3.80	-

Shad and Khan (1988)

3. WEED POPULATION/DENSITY

Increase in weed population has a direct effect on reduction in crop yield. At very low weed densities, there is no effect on crop yield, and as weed density continues to increase, crop yield drops quickly but never goes completely to zero. Even very high weed densities do not eliminate all crop plants. This represents most weed-crop competition data and provides a picture of what happens. A very general rule is for every unit of weeds grown, there will be one less unit of crop grown. Ahmad *et al.*, (1998) reported a linear decrease in wheat grain yield with an increase in weed density from zero to 105 with an interval of 15% (Table-14). Ansar *et al.*, (1996) recorded 8.92% decrease in grain yield of maize with 12 plants of *T. portulacastrum* m^{-2} (Table-15).

Table-14 Losses of Grain Yield by Weed Infestation in Wheat

Weed density (%)	**Grain yield (t ha^{-1})**	**Decrease over weed free (%)**
0 (Weed free)	4.66	-
15	4.06	12.87

30	3.83	17.81
45	3.73	20.00
60	3.53	24.24
75	3.40	27.00
90	3.10	33.47
105	3.00	35.62

Ahmad *et al.* (1998)

Table-15 Effect of *Trianthema portulacastrum* Density on Grain Yield of Maize

***T. portulacastrum* density**	**Grain yield (t ha^{-1})**	**Decrease over check (%)**
Zero (check)	3891	-
4	3739	3.91
8	3788	2.65
12	3544	8.92

Ansar *et al.* (1996)

4. DURATION OF WEED INFESTATION

The duration of weed-crop competition and the time of weed elimination have a great influence on crop growth and yield. Longer the period weeds remain in crop more will be the yield losses. Tables-16-23 show linear decrease in yields of different crops under field conditions with an increase in duration of weed infestation. Ghafoor and Sadiq (1991) and Akhtar *et al.*, (2000) reported a maximum of 29.36% and 22.15% decrease in grain yield of wheat, respectively due to full season weed competition. In cotton 13.75% decrease in seed cotton yield due to full season competition was reported by Saeed *et al.*, (1980) but in another experiment conducted by Makhdoom and Memon (1981) this figure was 90%. The studies conducted by Ahmad and Majid (1977), and Shad and Khan (1988) in rice revealed that presence of weeds till harvest caused 55 and 27% decrease in paddy yield than weed free situation. Tanveer *et al.*, (1998) demonstrated that keeping gram field weeds free all season increased grain yield by 31% over no weeding. Naeem *et al.*, (1999) reported 31.27% decrease in mungbean yield due to full season competition with weeds.

Table-16 Grain Yield of Wheat as affected by Competition of *Phalaris minor** with Wheat for different time Periods

Treatment Weed free	Grain yield (kg ha^{-1})	Decrease over weed free till harvest (%)
Till harvest	4285	-
4 WAE	4278	0.16
6 WAE	4206	1.84
8 WAF	3828	10.66
10 WAE	3302	22.94
12 WAE	3271	23.64
14 WAE	3175	25.90
16 WAE	3109	27.44
Weedy till harvest	3027	29.36

Ghafoor and Sadiq (1991)

WAE = Weeks after emergence * = 200 plants m^{-2}

Table-17 Effect of Weed Competition on Grain Yield of Wheat

Weed-crop competition duration	Grain yield (kg ha^{-1})	Decrease in yield over zero correction (%)
Zero competition	6.41	-
Competition for 4 WAS	6.07	5.30
Competition for 6 WAS	5.84	8.89
Competition for 8 WAS	5.68	11.39
Competition for 10 WAS	5.33	16.85
Full season competition	4.99	22.15

Akhtar *et al* (2000)

Table-18 **Effect of Weed Competition on Yield of Seed Cotton**

Treatment Period in which weeds were allowed to grow	Seed cotton yield (kg ha^{-1})	Decrease over zero competition (%)
Zero	778	-
2 WAP	777	0.13
4 WAP	743	4.50
6 WAP	737	5.27
All season	671	13.75
After crop was 2 weeks old	687	11.69
After crop was 4 weeks old	710	8.74
After crop was 6 weeks old	734	5.65
After crop was 8 weeks old	744	4.37
After crop was 10 weeks old	766	1.59

Saeed *et al*. (1980)

WAP = Weeks after planting

Table-19 **Seed Cotton Yield As Affected By Weedy and Weed Free Periods**

Name of treatment	Seed cotton yield (kg ha^{-1})	Increase in seed cotton yield (%)
Weed free full season	1822	90
Weed free first 8 weeks	1696	78
Weed free first 6 weeks	1557	62
Weed free first 4 weeks	1455	52
Weed free first 2 weeks	1368	43
Weedy full season	959	-
Weedy first 8 weeks	1315	37
Weedy first 6 weeks	1421	48
Weedy first 4 weeks	1544	61
Weedy first 2 weeks	1645	72

Makhdoom and Memon (1981)

Table-20 Effect of Weed Control Duration on Paddy Yield of Rice (Basmati-370)

Treatments Weed control for	Grain yield (kg ha^{-1})	Decrease over weed free till harvest (%)
10 DAT	1873	2.23
20 DAT	1973	7.69
30 DAT	3002	63.86
40 DAT	3318	81.11
50 DAT	2905	58.57
60 DAT	3234	76.53
70 DAT	3414	86.35
80 DAT	2532	38.21
Weed free	1069	122.10
No weeding	1832	-

Ahmad and Majid (1977)

Table-21 Effect of the Duration of Weed Competition on the Yield of Rice (Basmati-370)

Duration (weeks)	Paddy yield (kg ha^{-1})	Decrease over zero duration (%)
0-0	3.10	-
0-2	3.02	2.58
0-3	3.08	0.64
0-4	2.98	3.87
0-6	2.72	12.26
0-8	1.86	40.00
0-till harvest	2.26	27.09

Shad and Khan (1988)

Table-22 Effect of Different Levels of Weed Management on Grain Yield Of Gram in Irrigated Condition

Levels of weed management	Grain yield (kg ha^{-1})	Increase in yield over no weeding (%)
Weed free all season	963	31.00
Weeding at 4 WAE	904	23.00
Weeding at 6 WAE	883	20.14
Weeding at 8 WAE	825	12.24
Weeding at 10 WAE	771	4.90
Weeding at 12 WAE	757	3.00
No weeding	735	-

Tanveer *et al.* (1998)

WAE = Weeks after emergence

Table-23 Grain Yield of Mungbean as Affected by different durations of weed competition

Weed competition duration	Grain yield (kg ha^{-1})	Decrease over zero competition (%)
Zero	1407	-
10 DAE	1398	0.64
20 DAE	1369	2.70
30 DAE	1200	14.71
40 DAE	1080	23.24
50 DAE	969	31.13
Full season	967	31.27

Naeem *et al.* (1999) DAE = Days after emergence

COMPONENTS OF COMPETITION

The primary things plants compete for are nutrients, water and light. When any one is lessened, others can not be used effectively. Characteristics that could impar competitiveness for soil factors to a plant include: (1) early/and fast root penetration in t the soil, (2) high root density, (3) high root-shoot ratio, (4) high root length: root weigh (5) high proportion of root system actively growing, (6) long root hairs, and (7) hig uptake potential for the nutrient.

1. COMPETITION FOR NUTRIENTS

Nitrogen, phosphorus, and potassium are the primary plant nutrients, and nitrogen is the most important. Success in gaining nutrients may lead to more rapid growth and successful competition for water and light.

In a crop heavily infested with weeds, it seems logical that more fertilizer would reduce nutrient competition. Competition does not occur until the immediate supply falls below combined demand, if supply is increased, competition should decrease. Actually, fertilization usually stimulates weed growth to the crop's detriment. With low fertility, competition is primarily for nutrients, however, with high fertility, competition is just as vigorous, and primarily for light. Yields in unweeded, fertilized plots are usually equal to those in weeded, unfertilized plots.

In general, weeds have a large nutrient requirement and will absorb as much or more than crops. Nitrogen is the first nutrient to become limiting in most instances of weed-crop competition. The nitrate ion is not held strongly in soil and is highly mobile. Nitrogen depletion zones are likely to be quite wide and similar to those for water. Therefore, rooting depth and root area of plants determine the ability to obtain resources, and relative competitiveness of nitrogen is largely determined by the soil volume occupied by the roots of competing species. Even though nitrogen competition can be mainly determined by relative root volumes and spatial distribution of the weed and the crop, the differences among species in their rate of utilization may also be a factor.

Movement of phosphorus and potassium is slow compared to nitrogen and they move over shorter distances. Smaller depletion zones minimize inter plant competition. Competition for phosphorus and potassium is therefore most likely to occur after plants are mature and have extensive, overlapping root development.

While competition for nitrogen can sometimes be overcome by nitrogen fertilization, this is rarely for phosphorus and potassium. It may be possible to prevent or delay weed invasion of perennial crop with fertilizer. Nutrient removed by some important weeds in irrigated and rainfed conditions under different duration, densities and fertilizer application methods are presented in Tables 24 to 32.

Phalaris minor and *Chenopodium album* infesting wheat crop utilized a maximum of 16.05, 2.51, 10.24 kg N, P & K ha^{-1} and 5.17, 0.82, 7.76 kg N, P & K ha^{-1}, respectively (Tanveer *et al.*, 1998b; 1999; 2001a; 2001b). Akhtar *et al.*, (2000) found that from a full season weedy wheat field, weeds removed 6.16 kg N ha^{-1} .On the other NPK removal by weeds at 100% density in wheat was 6.03, 0.29, and 24.36 kg ha^{-1} (Ahmad *et al.*, 1998). Naeem *et al.*, (1994a) estimated that nutrient removal was maximum (9.66, 31.5 and 84.2 mg NPK m^{-2}) by *Asphodelus tenuifolius* in an area with 150-300 mm rainfall, *Convolvulus arvensis* (100.9, 42.7 and 480 mg NPK m^{-2}) in an area with 300-500 mm rainfall, *Fumaria indica* (306.8, 154.8, 185.8) mg NPK m^{-2}) in an area with 500-1000 mm rainfall, and by *Veronica didyma* (183.8, 135.9, 189.7 mg NPK m^{-2}) in an area with 1000-1500 mm rainfall.

Tanveer *et al*.(1998b; 1999; 2001b) found that broadcast incorporate application of fertilizer in wheat elevated the nutrient removal by weeds than side placement of fertilizer. Nitrogen removal by *C. album* in gram was 3.53 kg ha^{-1} when it was allowed to compete for 10 weeks after emergence (Tanveer *et al*. 1998a).

Table-24 **Nutrient uptake by *Phalaris minor* and *Chenopodium album* in Wheat under different competition periods**

Competition period	*P.minor*			*C. album*		
	Nutrient uptake kg ha^{-1}			Nutrient uptake kg ha^{-1}		
	N	P	K	N	P	K
3 WAE	2.33	0.19	1.32	1.14	0.20	1.01
4 WAE	2.17	0.29	1.14	1.59	0.28	1.63
5 WAE	3.37	0.34	1.92	1.72	0.33	1.77
6 WAE	5.41	0.61	3.95	2.90	0.75	2.69
7 WAE	8.79	1.06	7.95	. 4.97	0.67	4.42
8 WAE	11.98	1.12	10.24	5.17	0.82	6.16
Full season	16.05	2.51	9.23	3.65	0.51	7.76

Tanveer *et al*. (1998b, 1999, 2001a, 2001b)

Table-25 **Effect of Nitrogen and Competition Duration on Nitrogen Uptake by Weeds in Wheat**

N level kg ha^{-1}	N uptake by weeds kg ha^{-1}
0	1.7
100	2.63
150	3.50
Weed-crop competition for	
4 WAS	1.23
6 WAS	1.66
8 WAS	2.60
10 WAS	4.00
Full season competition	6.16

Akhtar *et al*. (2000)

Table-26 Nutrient Losses by Weeds in Wheat

Weed density (%)	Nutrient losses kg ha^{-1}		
	N	P	K
15	3.23	0.14	13.33
30	3.40	0.15	14.46
45	3.50	0.16	15.70
60	4.43	0.21	19.69
75	5.10	0.23	21.43
90	5.53	0.24	22.30
105	6.03	0.29	24.36

Ahmad *et al.* (1998)

Table-27 Effect of Fertilizer Application Methods on Nutrient uptake (Two Years Mean) by *Phalaris minor* and *Chenopodium album* in Wheat

Fertilizer application method	*P.minor* Nutrient uptake kg ha^{-1}			*C. album* Nutrient uptake kg ha^{-1}		
	N	P	K	N	P	K
Side placement	6.89	0.83	4.74	2.49	0.4	-
Broadcast incorporate	7.60	0.95	5.75	3.53	0.62	-

Tanveer *et al.* (1998b 1999, 2001b)

Table-28 Nutrient Uptake by different weeds and Wheat of Rainfed Wheat Fields in Areas with an Annual Rainfall 150-300 mm (Punjab, Pakistan)

Weeds	N (mg m^{-2})	P(mg m^{-2})	K(mg m^{-2})
Asphodelus tenuifolius	91.6	31.5	84.2
Convolvulus arvensis	75.2	23.7	62.0
Euphorbia dracunculoides	9.2	2.5	7.4
Fumaria indica	3.3	0.9	2.2

Malcolmia cabulica	5.1	1.5	3.4
Tribulus terrestris	2.0	0.6	2.1
Trigonella monantha	1.4	0.4	1.4
Wheat	333.8	165.3	538.2

Naeem *et al.* (1994a)

Table-29 **Nutrient Uptake by Different Weeds and Wheat of Rainfed Wheat Fields in Areas with an Annual Rainfall 300-500 mm (Punjab, Pakistan)**

Weeds	N ($mg\ m^{-2}$)	P($mg\ m^{-2}$)	K($mg\ m^{-2}$)
Anagallis arvensis	4.1	2.7	4.2
Asphodelus tenuifolius	35.8	12.2	24.0
Carthamus oxyacantha	37.5	11.2	20.4
Convolvulus arvensis	100.9	42.7	48.0
Fumaria indica	32.8	11.6	20.9
Trigonella monantha	38.0	12.9	23.6
Vicia sativa	14.8	5.5	7.7
Wheat	622.9	213.8	470.3

Naeem *et al.* (1994a)

Table-30 **Nutrient Uptake by Different Weeds and Wheat of Rainfed Wheat Fields in Areas with an Annual Rainfall 500-1000 mm (Punjab, Pakistan)**

Weeds	N ($mg\ m^{-2}$)	P($mg\ m^{-2}$)	K($mg\ m^{-2}$)
Avena fatua	47.3	16.0	27.2
Buglossoides arvensis	63.1	35.8	61.4
Chenopodium album	22.5	9.3	31.8
Convolvulus arvensis	9.2	3.1	5.1
Fumaria indica	306.8	154.8	185.8
Lathyrus aphaca	15.8	6.4	9.4
Medicago polymorpha	192.7	69.6	111.2
Melilotus indicus	28.8	33.3	33.4

Phalaris minor	16.0	11.0	12.5
Ranunculus muricatus	46.7	14.3	34.5
Silene conoidea	51.6	31.9	71.1
Torilis leptophylla	16.6	4.5	10.4
Veronica didyma	21.0	11.2	24.2
Vicia sativa	53.6	17.9	30.1
Wheat	1510.0	603.3	1362.9

Naeem *et al.* (1994a)

Table-31 Nutrient Uptake by Different Weeds and Wheat of Rainfed Wheat Fields in Areas with an Annual Rainfall 1000-1500 mm (Punjab, Pakistan)

Weeds	N (mg m^{-2})	P(mg m^{-2})	K(mg m^{-2})
Avena fatua	38.6	34.6	37.7
Buglossoides arvensis	12.7	11.3	13.5
Galium aparine	25.4	21.5	24.7
Lamium amplexicaule	128.2	65.5	130.5
Lepedium sativum	11.7	14.8	10.9
Medicago polymorpha	72.2	51.0	58.1
Ranunculus muricatus	26.8	17.6	24.6
Stellaria media	38.2	37.8	59.5
Veronica didyma	183.8	135.9	189.7
Vicia sativa	16.8	7.3	10.1
Wheat	1327.7	946.8	1338.3

Naeem *et al.* (1994a)

Table-32 Effect of Different Levels of Weed Management on Nitrogen uptake by *Chenopodium album* in Gram

Levels of weed management	N-uptake (gm^{-2})
Weeding at 4 WAE	0.32
Weeding at 6 WAE	0.59

Weeding at 8 WAE	1.76
Weeding at 10 WAE	3.53
Weeding at 12 WAE	2.84
No weeding	2.21

Tanveer *et al.* (1998a)

WAE = Weeks after emergence

2. COMPETITION FOR WATER

Water is often the primary factor limiting crop production in many irrigated areas and is probably the most critical of all plant growth requirements. Weeds require just as much, or more water than crops, and, are often more successful in acquiring it. The degree of competition for water between a desired plant and weed is determined by the root volume occupied by each and will be greatest when roots closely intermingle and crops and weeds try to obtain water from the same volume of soil. Less competition occurs if roots of crops and weeds are concentrated in different soil areas. Depending upon the types of root systems of the desired plant and the weed and the supply or distribution of water in the soil profile, either extensive lateral or extensive vertical distribution can impart a competitive advantage for one species over the other.

More competitive plants have faster growing, large root systems so they are able to exploit a large volume of soil quickly. If plants have similar root length, those with more widely spreading and branched root systems will have a comparative advantage in competition for water. In general, for producing equal dry matter, weeds transpire more water than do most of our crop plants. Hence, in dry land agriculture the actual evapotranspiration from the weedy crop fields is much more than the evapotranspiration from weed-free crop field. In such situation, during a dry spell the weedy crops exhibit wilting or other moisture stress symptoms much earlier than a weed-free crop.

3. COMPETITION FOR LIGHT

Neighboring plants may reduce light supply by direct mutual shading. Leaves are the site of light competition. Leaves that first intercept light may reflect it, absorb it, convert it to photosynthetic products, convert it to heat, or transmit it. If transmitted, the light is filtered so that it reaches lower leaves dimmer and spectrally altered. Anytime one leaf is shaded by another, there is competition for light.

Light competition is most severe when there is high fertility and adequate moisture because plants grow vigorously and have larger foliar areas. Plants with large leaf area indices have a competitive advantage and normally out compete plants with smaller leaf areas. Successful competitors do not necessarily have more foliage but do have their foliage in the most advantageous position for light interception. Plants with horizontal leaves are more competitive for light than those with upright leaves. Plants with opposite leaves are probably less competitive than those with alternate leaves. Plants that are tall or erect have a competitive advantage for light over short, prostrate plants. A heavily shaded plant suffers reduced photosynthesis, leading to poor growth, a smaller root system, and a reduced capacity for water or mineral uptake.

FACTORS FOR WHICH PLANTS GENERALLY DO NOT COMPETE

Plants and weeds that emerge at the same time rarely compete for space even though plant density may be high. When plants emerge at different times, the first plant that occupies an area will tend to exclude all others and have a competitive advantage and, in this sense, plants compete for space by occupying space first. For crops like sugarcane, potato which take long time for emergence, weeds grow without any competition and sometimes over grow the crop. There is no evidence that plants compete for heat energy or agents of pollination or oxygen.

CRITICAL PERIOD OF WEED CROP COMPETITION

The critical period of weed crop competition is defined as the (i) shortest time span in the life cycle of a crop when weeding will result in the highest economic returns or (ii) it is the period in the life cycle of the crop during which there is maximum loss in grain yield due to competition by weeds. In general, initial growth stages of crops are very sensitive to competition by weeds and there is maximum loss to the crop if weeds are not removed during this period. With passage of time, crop establishes and the severity of loss due to weeds gets decreased. So, it is very essential to control weeds during initial period which is most critical for weed crop competition. These uncontrolled weeds cover the crop and sometimes may result in crop failure. So keeping crop free from weeds by any method helps in improving yield drastically. The crop yield levels obtained by managing the weeds during this period should provide crop yields sufficiently close to those obtained by the full season freedom from weeds. Critical period of weed crop competition is location specific, crop specific and vary with several weed factors like the time of weed occurrence, weed density and weed type etc. It can be concluded that each crop has a critical period of weed competition and normally lies in the early period of growth among annuals while it may differ in perennial crops.

Ghafoor and Sadiq (1991) reported 6-8 weeks after emergence as critical period of weed-crop competition in wheat (Table-16). According to Akhtar *et al*., (2000) in wheat critical period of weed-crop competition lies in between 4-6 weeks after sowing (Table-17). Similarly Saeed *et al*. (1980) and Makhdoom and Memon (1981) found that critical period of weed crop competition is 6 weeks after planting and from 2 to 8 week after planting, respectively in cotton (Tables-17 & 18). Ahmad and Majid (1977) and Shad and Khan (1988) found that in rice good weed control was necessary for up to 40 days after transplanting (Tables-20 & 21). In gram, Tanveer *et al*., (1998a) found 6 weeks after emergence critical for competition from weeds (Table-22). In rapidly growing crop like mungbean (Table-23) weeds must be controlled from 10 to 20 days after emergence (Naeem *et al*. 1999).